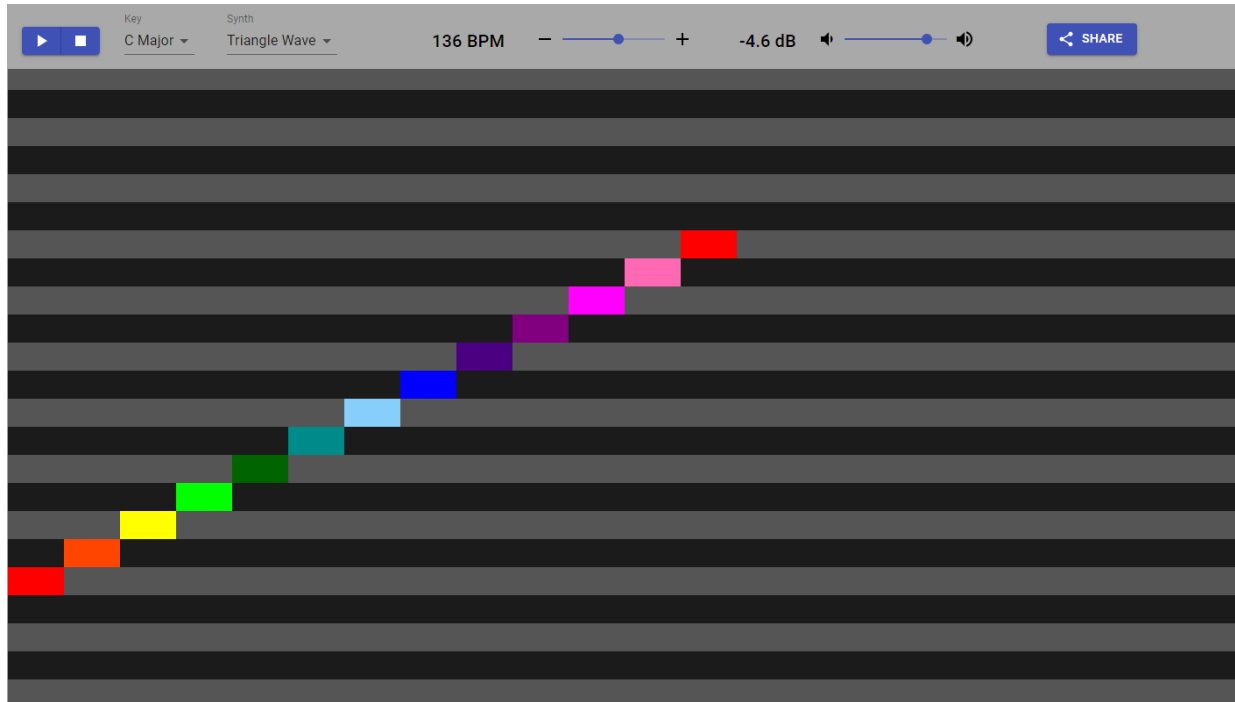# Relatable DAW

Developing an Interactive Digital Tool for Teaching Music Theory Concepts to High School Band Students Through Composition

This report represents the work of one or more WPI undergraduate students submitted to the faculty as evidence of completion of a degree requirement. WPI routinely publishes these reports on the web without editorial or peer review.

By:

Luke Bodwell

Date: July 18, 2021

Report submitted to:

Professor VJ Manzo, Advisor

Abstract

This report details the development process of *Relatable DAW*, a web-based interactive tool designed to teach music theory concepts like scale degrees and intervallic relationships between notes to high school students in concert band or other related music classes through an abstract compositional lens. An interview with a high school band director was conducted in order to ascertain information on the use of digital tools in a classroom setting to aid in student understanding of musical concepts. The insight and feedback gained from this interview served as an aid to inform the development and refinement of the application.

Table of Contents

Table of Figures

Chapter 1: Introduction

This chapter serves as an introduction to the general areas of focus of this project and the motivations behind it. I will describe my own experiences in high school band, explain the shortcomings of the Maine state music standards, and propose a solution to the lack of student interest and understanding in music theory concepts through the use of an educational digital tool that makes use of interactive composition through a novel interface.

High School Concert Band

In my own personal experience, music composition was undertaught in my high school band program. I had an interest in composition and therefore decided to go out of my way to learn more about it on my own, but for those who never get the exposure to it, they may be missing out on what is an important part of music education. I believe composition can be best used in facilitation of developing additional music theory skills. An area that many of my peers in high school particularly struggled with was identifying intervallic relationships between pitches and understanding the relationships between scale degrees and their tonal functions. I went through concert band throughout both middle and high school in the state of Maine and was anticipating interviewing a band director in Maine as part of this project, so I therefore decided to reference the official Maine state music standards to compare them to my anecdotal experiences. Interestingly, these standards state students being able to "…analyze and evaluate musical ideas expressed in their own compositions or the compositions of others" as an indicator of high school students meeting expectations, though there is little to no mention of higher-level music theory concepts like intervals or scale degrees. For more information on these standards, see ***Appendix A: Maine State Music Standards***.

I found this discrepancy in the standards puzzling as intervals and scale degrees are essential to understanding and analyzing harmonic and melodic intent in a composition and frankly go hand-in-hand with composing. Additionally, in my own experience and contrary to what the standards may suggest, we actually spent a decent amount of time studying these theory concepts in high school through the use of digital tools. With that said, none of these tools were particularly engaging and they did not promote interactive learning for students. Online tools like musictheory.net which can be used for things like interval ear training practice tend to be rather limited and cut-and-dried, if you will. They present little to no interactivity or novelty to the user and are essentially glorified flash cards with an auditory element.

Figure 1.1: Interval Ear Training on musictheory.net
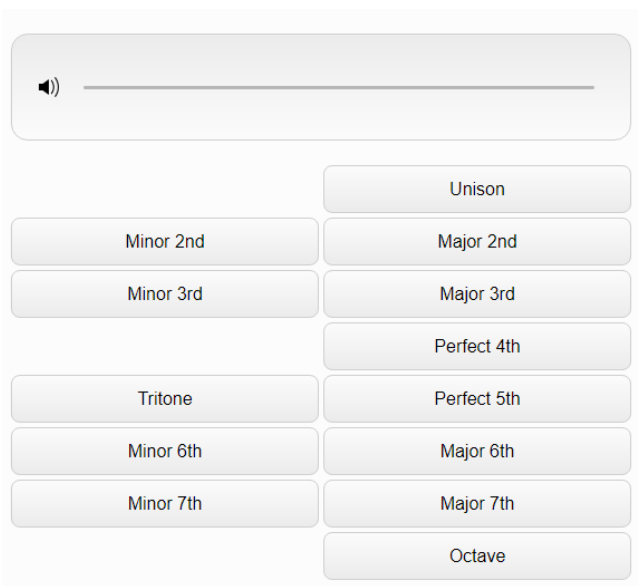
A Relational Digital Audio Workstation

The approach of using tools like musictheory.net may work for some students, but a more engaging tool in which students can be more directly involved in facilitating their own learning and producing some level of spectacle in the process has the potential to be much more effective for certain students. With this in mind, I settled on composition as well as concepts like scale degrees and intervals as the main areas of focus for the development of my application. My working idea was to create a simplified DAW (digital audio workstation) with one major caveat—instead of using sheet music notation, note names, or a grid with corresponding piano keys, every note's pitch would be defined relative to either the tonic of the key or some another note preceding it. The following chapter will touch more on the specifics of what a digital audio workstation is as well as detail how this application would incorporate music theory concepts in a unique and novel way and provide a more in-depth explanation of what said concepts actually are.

Chapter 2: Background

This chapter will cover background information surrounding the musical concepts the application addresses that are necessary to understanding the full extent of its functionality and the novelty of its interface. Details regarding other digital audio workstations and how the proposed application sets itself apart from them will be addressed. Additionally, a more thorough explanation of scale degrees and intervals, the music theory concepts the application is attempting to teach through composition in a more technical and abstract form, will follow.

Other Digital Audio Workstations

At the end of the previous chapter, I presented the concept of a digital audio workstation that operates on a relationship-based system, but what exactly is a digital audio workstation? There are a lot of different types of DAWs out there, and some might disagree on what features a piece of audio-related software needs to offer in order to be classified as one, but for the sake of simplicity, a DAW can be defined as software or hardware solution that allows the user to manipulate digital audio through some sort of interface. Many modern DAWs like FL Studio, Ableton Live, Avid Pro Tools, and Cubase, etc. have a particular focus on composing music, but this is not strictly a requirement, as programs like Audacity can also be considered a digital audio workstation given the established definition. Typically, these music-oriented DAWS tend to have features like built-in synthesizers as well as support for external ones, a timeline view of all the samples and instrumental parts that are part of the composition, and a 'piano roll' sequencer that allows the user to lay out notes along a grid in which their horizontal position represents the time at which they are triggered and their vertical position represents their pitch. Individual parts created with this sequencer can then be arranged along the timeline. The below figure depicts a screenshot of the piano roll sequencer of FL Studio, a DAW known for being particularly user-friendly and having a very interactive and responsive piano roll.

Figure 2.1: FL Studio Piano Roll
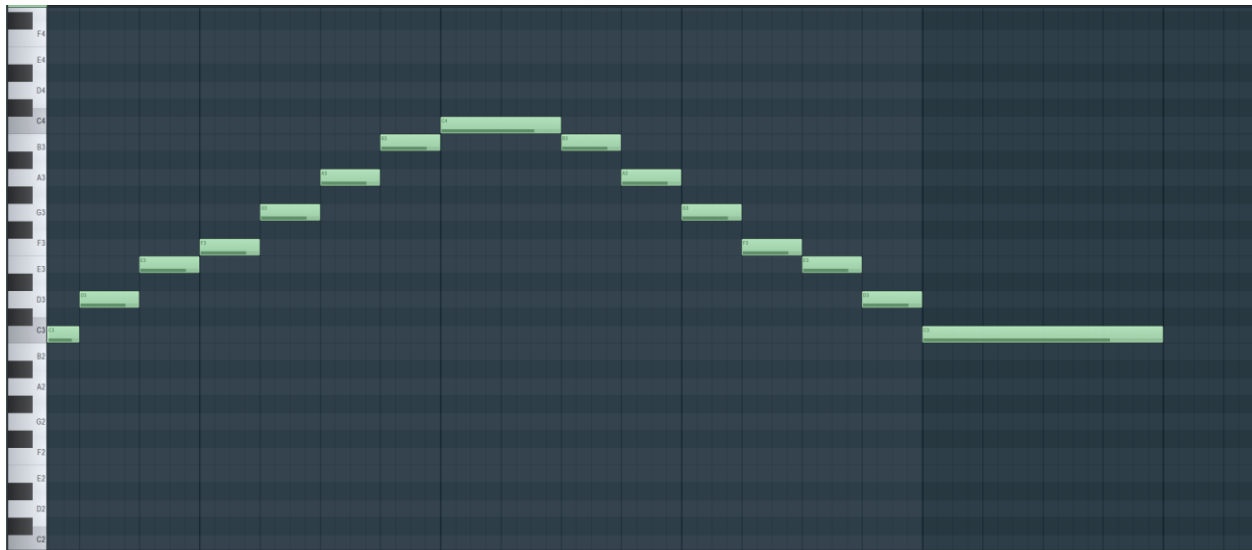
For my proposed application, synthesizer support would be limited but available in the form of built-in presets for simple oscillating waveforms like sine waves, triangle waves, square waves, and sawtooth waves. As for the timeline and sequencer, since my main design goal was to focus on the novelty of the mechanism through which users define the notes in their compositions, I felt it was not particularly important to support multiple instruments in a single project. Because of this I elected to combine the timeline and sequencer into a single view with the majority of the focus being placed on the sequencer. The FL Studio piano roll served as the primary inspiration for the sequencer in my application especially later in its development. With that said, one major aspect of the FL Studio piano roll that I did not want to make use of was its array of piano keys notated with note names. This feature is certainly helpful, but it goes against the central design philosophy of the proposed application. The idea is to get the user to think about the notes that are being put down in a different, more abstract way than they are likely used to as avenue for understanding the important role that music theory plays in composition.

Scale Degrees and Intervals

Scale degrees and intervals are important concepts in music theory and serve as the basis for interacting with this relational digital audio workstation. A scale degree refers to the position of a note within a scale relative to the tonic—or the first note—of the scale's key. A scale is a collection of certain notes ordered by pitch, and which notes are included in a scale is determined by what type of scale it is. For the purposes of both the application and the paper, we are going to be focusing only on major scales for now. A tonic (which is also sometimes referred to as a keynote, root, or tonal center among other things) is the note that a scale starts and ends on and can be used to help determine a song's key and therefore what diatonic notes will be included in it. Of course, many compositions will also make use of non-diatonic, chromatic notes to bring variety to and enhance their melodic and harmonic elements, but the diatonic notes are what

gives a key its identity. Each scale degree is named according to when its pitch is played in the scale regardless of octave, as can be seen in the following example for the C Major scale. Once reaching the C an octave above the starting C, the pattern loops back around to the beginning.

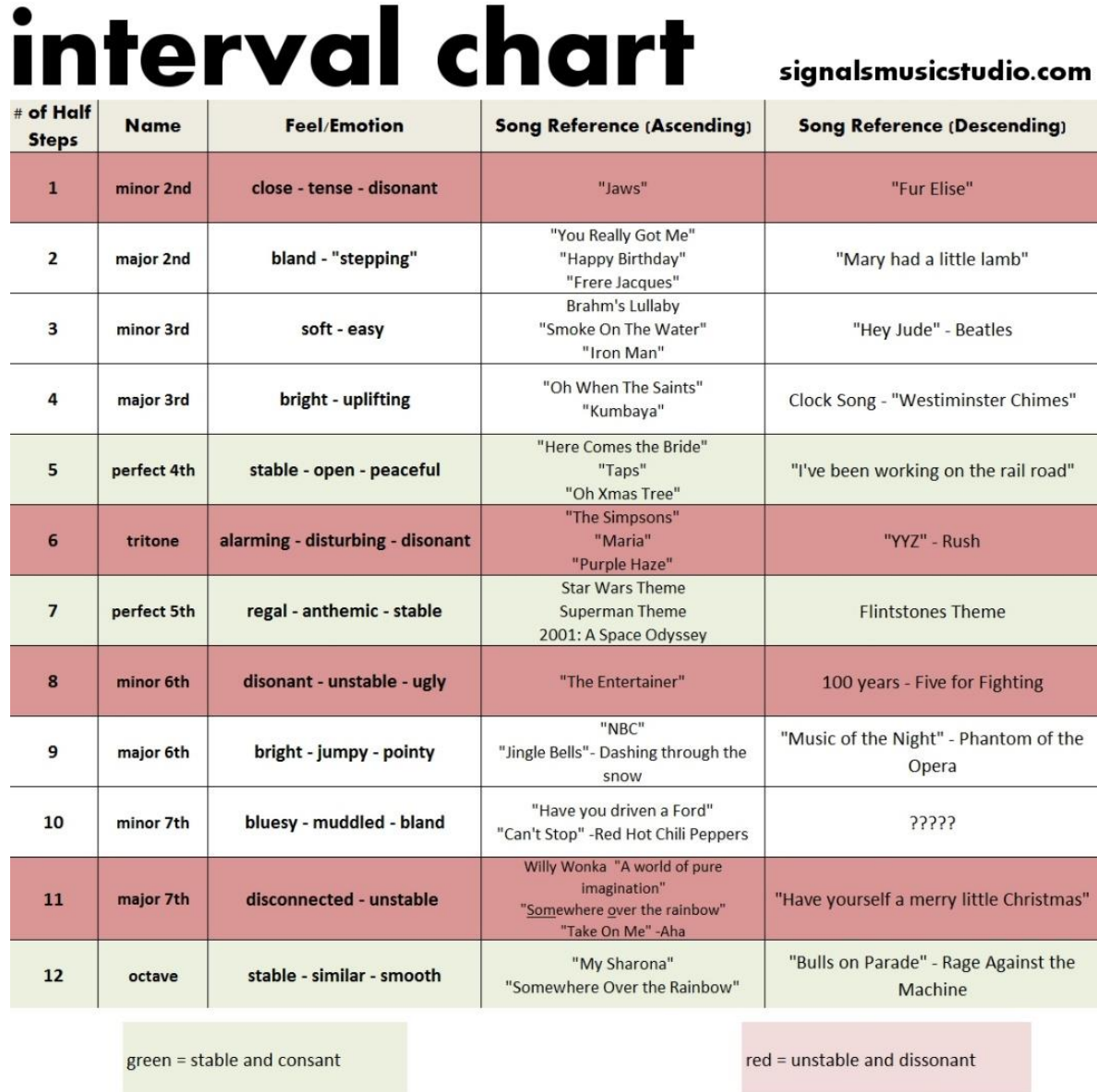**Figure 2.2:** Scale Degrees in C Major

An interval is defined as the distance between any two notes but is usually used to represent the distance between the tonic of the key and some arbitrary scale degree. Typically, this distance is measured from the lower note to the higher one. This is called an ascending interval; however, intervals can also be measured in the opposite direction. It is important to be aware that the resulting notes of ascending and descending intervals relative to a common note are actually not equivalent in all cases except three—when the interval is a tritone, perfect unison, or perfect octave. The tritone is unique in that it is the one and only interval where the resulting note is equidistant from the note the interval is relative to—usually the tonic—in both directions. In the case of the perfect unison, the resulting note will always be the same as the note that the interval is relative to and the direction is therefore irrelevant. As seen in *Figure 2.3* above, the perfect unison is also sometimes simply labeled as the first of the scale. As for the perfect octave, the resulting note has the same pitch albeit an octave higher or lower than the octave of the tonic. Because of this, the perfect octave is often just referred to as a perfect unison with the caveat that it is in a different octave than the starting note. As an example of this behavior, a perfect fifth above G is D and a perfect fifth below G is C, meanwhile a tritone both above and below G is C# or Db depending on whether you think of the tritone as an augmented (raised by one semitone) fourth or a diminished (lowered by one semitone) fifth. The two notes are enharmonically equivalent, meaning they have the same pitch but are notated differently. Similarly, the note in perfect unison with G is obviously G regardless of direction and a perfect octave both above and below G is still just a G.

Each interval has a unique sound that makes it identifiable regardless of which two pitches it represents the distance between. For many musicians, the easiest way to identify an interval is to compare it to songs they already know and figure out what it sounds similar to. For example, an ascending minor third can be identified as sounding like the first two notes in the main riff of *Smoke on the Water*. Likewise, an ascending major sixth can be identified as sounding like the first two notes of the NBC chime. There are similar rules for all intervals, and each one evokes a different sort of feeling that gives it different harmonic and melodic function in composition. A comprehensive discussion of interval naming conventions and what these names represent is outside of the scope of this paper, but suffice it to say, scale degrees and intervals are two music theory concepts that are very closely related, and both are vital to

composition. Below is an infographic that should at least facilitate a basic understanding of the purpose of intervals and how the identification of them works.

Figure 2.3: Interval Chart

interval chart
signalsmusicstudio.com

# of Half Steps	Name	Feel/Emotion	Song Reference (Ascending)	Song Reference (Descending)
1	minor 2nd	close - tense - disonant	"Jaws"	"Fur Elise"
2	major 2nd	bland - "stepping"	"You Really Got Me" "Happy Birthday" "Frere Jacques"	"Mary had a little lamb"
3	minor 3rd	soft - easy	Brahm's Lullaby "Smoke On The Water" "Iron Man"	"Hey Jude" - Beatles
4	major 3rd	bright - uplifting	"Oh When The Saints" "Kumbaya"	Clock Song - "Westiminster Chimes"
5	perfect 4th	stable - open - peaceful	"Here Comes the Bride" "Taps" "Oh Xmas Tree"	"I've been working on the rail road"
6	tritone	alarming - disturbing - disonant	"The Simpsons" "Maria" "Purple Haze"	"YYZ" - Rush
7	perfect 5th	regal - anthemic - stable	Star Wars Theme Superman Theme 2001: A Space Odyssey	Flintstones Theme
8	minor 6th	disonant - unstable - ugly	"The Entertainer"	100 years - Five for Fighting
9	major 6th	bright - jumpy - pointy	"NBC" "Jingle Bells"- Dashing through the snow	"Music of the Night" - Phantom of the Opera
10	minor 7th	bluesy - muddled - bland	"Have you driven a Ford" "Can't Stop" -Red Hot Chili Peppers	?????
11	major 7th	disconnected - unstable	Willy Wonka "A world of pure imagination" "Somewhere over the rainbow" "Take On Me" -Aha	"Have yourself a merry little Christmas"
12	octave	stable - similar - smooth	"My Sharona" "Somewhere Over the Rainbow"	"Bulls on Parade" - Rage Against the Machine

green = stable and consant

red = unstable and dissonant

https://signalsmusicstudio.com/wp-content/uploads/2017/11/Musical-Intervals-Ascending-and-Descending-Chart.jpg

Within the proposed application, any note in the 12-tone equal temperament system should be theoretically reachable from any parent note. This promotes creativity and presents a lot of choices for those who would like to take advantage of them, but the option is also there to use only the tonic as a parent note and think solely in terms of major, minor, and perfect intervals as well as the often alienated tritone relative to just one note. I mention the tritone specifically since, as alluded to above, it is the only interval representing a note that cannot be obtained by

raising or lowering the tonic by a major, minor, or perfect interval. It represents the note in between a perfect fourth and a perfect fifth, so it can be notated using an augmented fourth or diminished fifth but is often referred to as simply the tritone instead. For the sake of simplicity, I have elected to leave augmented and diminished intervals out of the application in general, but the tritone is included in order to preserve the goal of making any note reachable by defining it relative to any other note.

    As an example of this relational system in action in the context of the application, if the key is chosen to be G Major, the first note could be defined as in unison with the tonic and have a calculated pitch of G. From there, adding a new note and defining it as a perfect fifth above the previous note would give it a calculated pitch of D. If a third note defined as a perfect fourth above the first note, a fourth note defined as a minor second below the third note, and a fifth note defined as a major second below the fourth note are added, provided the rhythms are correct, you get the first phrase of the *Star Wars* main them: [G, D, C, B, A]. Change the key to Bb major for example, and you get: [Bb, F, Eb, D, C]. The intervallic consistency of the melody is preserved with all the notes having the same distance relative to each other as before. Using this framework for composition, the user does not have to think about individual pitches and which ones will sound good together, just the harmonic relationships between the notes. Because of this focus on relationships and a desire to make the application as accessible and user-friendly as possible, I felt the name *Relatable DAW* was rather appropriate.

Chapter 3: Methodology

The goal of this project was to develop an interactive, digital application that could be used by high school band students to aid in their understanding of music theory concepts like intervals and scale degrees as well as basic music composition techniques as these skills tend to be undertaught in high school band programs. In order to accomplish this goal, I created the following list of objectives:

Objective 1. Determine what tools and technologies would be best suited to developing the application and begin prototyping.

Objective 2. Meet with a high school band director and conduct an interview to obtain professional insight and knowledge on the use of digital tools and interactive media to facilitate learning in a concert band classroom setting.

Objective 3. Present a demonstration of a prototype of the application in the form of a minimum viable product to the band director and gather feedback on its features.

Objective 4. Use the findings gathered from the interview and demonstration to aid in the further development of the application.

This chapter outlines the approach taken to achieve these objectives.

Initial Testing and Development

I decided early on to make the application web-based because it allows the most flexibility for use with various devices and would be best suited for supporting collaborative editing features. Due to the nature of this project being a solo effort, despite the benefits of native desktop and mobile apps, developing and maintaining separate codebases for different platforms would prove impossible in the time allotted. Because of this, I decided to make use of the MERN stack, a popular JavaScript-based web application technology stack. The first component of the stack, the *M*, is MongoDB, a non-relational database used for persistent storage of documents based on JSON (JavaScript Object Notation) syntax. The *E* is Express, a back-end web framework useful for developing REST (representational state transfer) application programming interfaces. The *R* is React, a front-end component-based web framework for developing user interfaces. Finally, the *N* is Node.js, an open-source JavaScript runtime environment based on Google's V8 engine.

The main choice here to make was using React as the front-end framework, as the other components of the stack are largely industry standard. I decided on React for two major reasons. It is what I am most familiar with and therefore most comfortable using, but it also plays nicely with both Electron and React Native, two frameworks that make use of JavaScript and embedded browsers to create desktop and mobile application from HTML-based markup. This allows for

potential expansion to additional platforms in the future without multiple drastically different codebases.

On top of the MERN stack, I made use of two core libraries to aid in handling music notation and audio processing, the similarly named yet quite different Tonal.js and Tone.js respectively. Though I was not entirely sure if it would pan out initially, I considered implementing real-time collaboration features using web sockets with the socket.io library early in development. I did ultimately end up using this library, but these features along with other things like database integration, OAuth 2 authentication through a Google account, and other systems were not developed until much later on in the project. Instead, at the time, I started working on audio synthesis tests and began developing data structures and algorithms for modelling intervallic relationships between notes, converting them into pitches, storing the relevant data, and making it available and reactively mutable throughout the global state of the application. These early tests were eventually developed into a minimum viable product to be shown to a professional band director as a technical demo. As the application grew in scope though, I ended up running into a lot of issues with integrating audio synthesis with the rest of the application and for a time was considering scrapping it altogether. I had hoped to have it ready in time for my meeting with the band director, but that unfortunately did not end up panning out.

Meeting with the Band Director

For the interview and application demonstration, I chose to reach out to my high school band director, Jake Sturtevant, the current director of instrumental music at Falmouth High School in Falmouth, Maine, in order to leverage his professional experience in working with high school band students to develop a more engaging and useful application. I created a list of interview questions to ask him with the aim of determining if his experiences line up with my own personal observations on the use of interactive media and digital tools in a high school band class and ascertaining his opinions on the value of composition and various music theory concepts. These questions were compiled primarily with the Maine state music standards and the usefulness of specific application features in mind. Following the preliminary interview questions, I then showed him a demonstration of a prototype of the application and used his insights to inform the further development of *Relatable DAW*. My findings from this meeting and how I applied them will be discussed in detail in the following chapter.

Chapter 4: Results

During my meeting with Jake Sturtevant in which I conducted an interview and showcased the application in the state it was in at the time, I acquired some invaluable insights into the way high school students learn as well as feedback on how the application could be improved going forward. In this chapter, I will discuss Sturtevant's opinions on the value of composition and music theory concepts in a high school concert band setting as well as the accuracy of the Maine state music standards when it comes to teaching these concepts. I will also focus on a few choice areas of feedback that particularly informed the further development of *Relatable DAW*. This feedback will primarily be centered around the user interface of the application and the importance of user interactivity. After discussing this feedback, I will present the steps I took to implement it in the application in the form of new and refined features. For a comprehensive list of all of Sturtevant's answers to the interview questions, see ***Appendix B: Interview Protocol***.

Findings from the Interview

One of the big questions I had for Sturtevant was what his opinions were on the value of both composition and music theory concepts and how important he feels they are to the overall high school band experience. Sturtevant has a background in composition and therefore states that he thinks "…it's a very important aspect for students to get out of the high school band experience." He went on to say that "…[he] really wanted to have [his] students, no matter what grade level [he] was teaching, to experience composition in some capacity," and that "it's really useful to be able to understand music at a much deeper level when working compositionally or even arranging." As for theoretical concepts, he "…[tries] to integrate [them] into compositional practices in some capacity in the high school band experience, so that students will be able to understand these are the building blocks that music is built on." His opinions on composition and music theory concepts served as an affirmation that the areas I was pursuing in the development of my application were indeed important.

In line with my own observations, Sturtevant also pointed out that he finds the Maine state music standards to be poorly worded and outdated in many ways. He explained to me that he makes use of "…a hybrid of the national music standards with the Maine state learning results in order to…reflect and represent what students should be able to do for skills at the high school level." He also noted that in addition to this hybrid model, he also pays a lot of attention to and makes use of what his colleagues are doing. "Through workshops and other conferences, [he] certainly [picks] up a lot of things to help plan [his] curriculum."

Another interesting insight I received from Sturtevant was that one of the skills he considers most important to teach to students learning how to compose is "to utilize an awareness of both subjectivity and objectivity." In order to support this framework for composition, the application's interface needed to be designed in such a way that it is intuitive and engaging, encouraging deliberate experimentation and providing tangible visual and auditory

feedback to the user. Sturtevant summed up his criteria for digital tools being worthy of his use in the classroom—"…a lot of them are really just visually engaging, they're interactive, and they allow for students to be learning concepts in a unique and different way than they would be in an in-person setting." He continued, "a lot of what I what I have been intrigued by, within the context of utilizing technology to teach particular concepts is the visual nature of it. Just being able to see it structurally laid out has been really helpful."

I felt that the concept of *Relatable DAW* could fit the above criteria in theory but needed a bit of work especially on the user interface side in order to become fully realized. I also asked Sturtevant what his thoughts were on the usefulness of features such as saving and sharing projects with other users and real-time collaborative editing. His response was that in order for "…students to be able to do some composition on their own utilizing technology, then sharing in any capacity is really important." With these findings fresh in my mind, I set out to continue the development of the application with three major goals in mind—overhauling the user interface, introducing more visual and auditory interactivity, and implementing collaborative features. For reference, *Figure 4.1* showcases the application in the state it was in at the time of my meeting with Sturtevant.

Figure 4.1: *Relatable DAW* Prototype
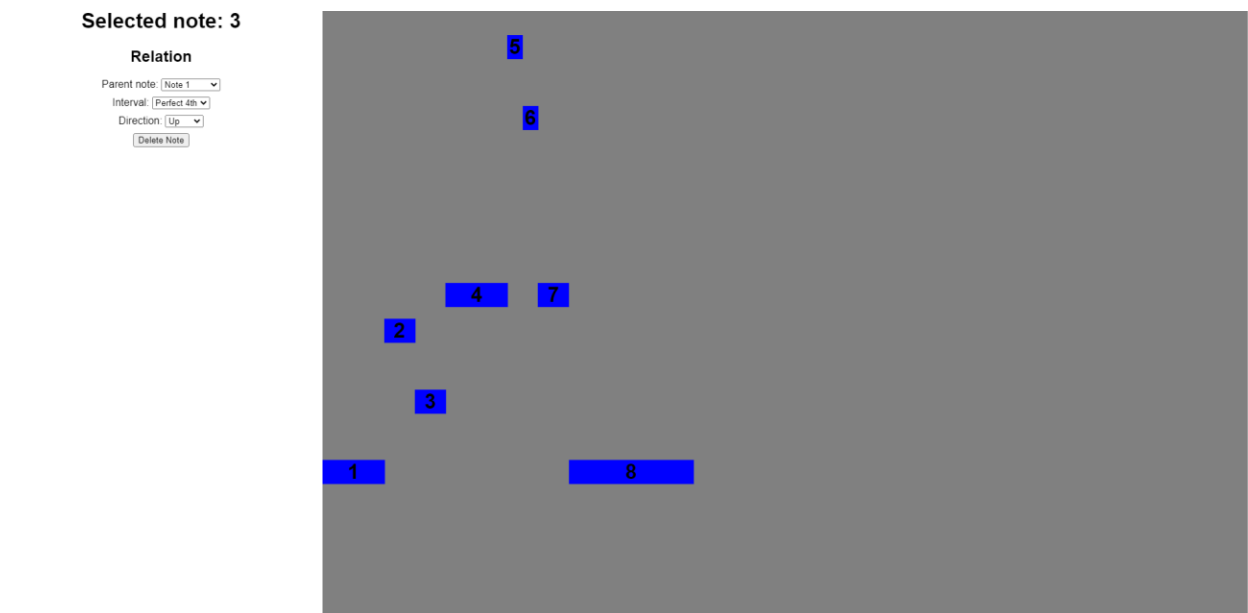

Refining the Application

The first major task I tackled after the meeting was re-writing the note rendering system from scratch. The version I showed to Sturtevant was inflexible, not scalable to different screen resolutions, and had limited support for multiple colors and note widths. The new system is much more responsive and allows for far more granular control. I took inspiration from an online tool called 'Hooktheory' shown to me by Sturtevant in deciding how to leverage colors in the

piano roll sequencer. I created an alternating pattern of one lighter and one darker tone of gray in order to differentiate the rows of the grid representing individual pitches. This is especially helpful in preventing the rows of the grid from blurring together when there exists a large vertical section with no notes placed.

For the notes placed in the sequencer themselves, I assigned each interval relative to the current key's tonic its own color spanning the RGB color spectrum. For example, in the key of C major, a C is red, another C an octave higher is also red, and the note equidistant between the two Cs, an F# (which, recalling from *Chapter 2: Background*, is a tritone apart from both Cs), is light blue. The gaps are filled in by the colors between these extremes, forming an extended rainbow of sorts if you were to write out a full chromatic scale in the sequencer. To better highlight the currently selected note and provide some visual feedback to the user, I also added an animated darkening effect that is applied on selection and removed on deselection. I also added transition animations to repositioning notes in order to make the action feel more responsive.

In order to improve the overall user experience, I overhauled the application to make use of Google's Material design system. I employed a library called Material UI to interface with React and make the application much more visually appealing and professional-looking, with a similar look and feel to the Google apps that people know so well. Another major improvement I made was to lock the sequencer to a specific size relative to the screen resolution and make it possible to pan the view in all directions with a mouse as well as scroll vertically. This prevents the entire site from having to be scrolled in order to see another part of the current composition's note sequence and allows the sidebar housing the note editor to be constantly in view. A look at the updated interface after taking Sturtevant's feedback into account can be seen in the following figure.

Figure 4.2: Updated *Relatable DAW* UI
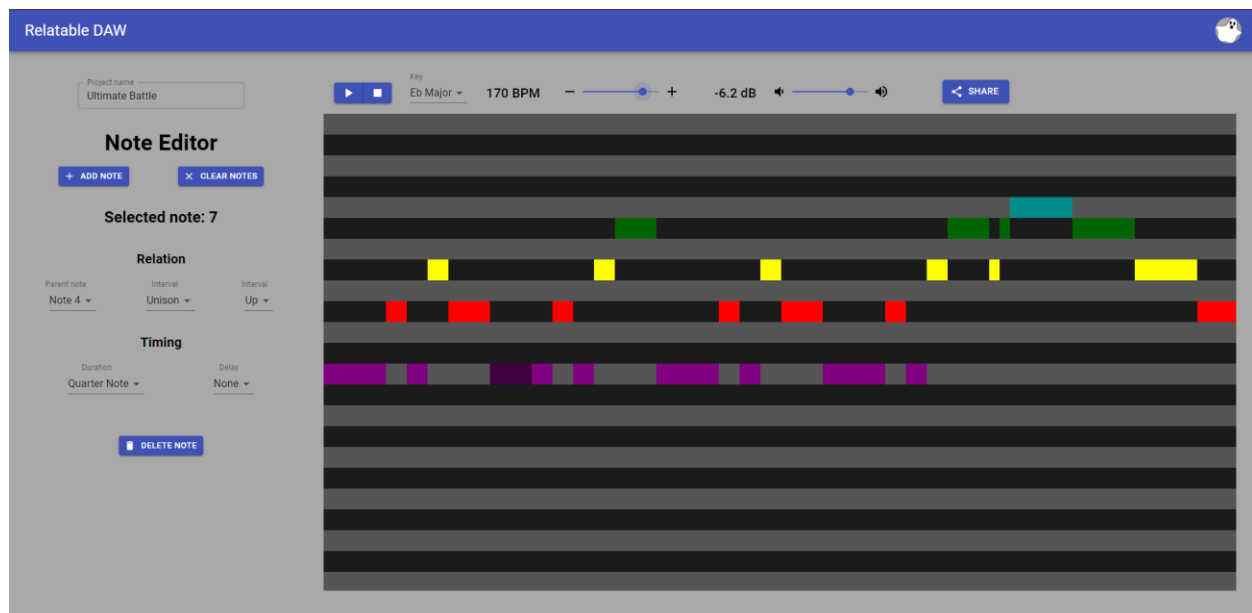
Sturtevant's comments on the importance of sharing compositions as well as immediate user feedback outlined above inspired me to focus on getting collaborative real-time editing and synthesized audio playback working as soon as possible as well. These were two rather daunting features that both involved a lot of overhead and relied on several other systems to act as building blocks for their functionality. I had both features in the back of my mind from the beginning but was unsure whether I would realistically be able to implement either in the time allotted for this project. Fortunately, I was able to get both working to a reasonable degree, however there is a lot of room for improvement to both features in the future.

Next Steps and Broader Outreach

The application was developed with the goal in mind of it being usable by anyone with a high-school level understanding of music theory concepts or higher. While its intended audience is students within a classroom setting, the only actual restriction of the application is that the user must have a Google account in order to authenticate themselves and use the full extent of the application's features. The application will be hosted online in such a fashion that it can be accessed by anyone who has the URL. More details on the accessibility of *Relatable DAW* and its further development can be found in the user manual in the following chapter. Additional improvements could be made to the application to increase its robustness in order to meet the needs of band directors in various high schools.

Additionally, throughout the development of the application, I have found that its interface has the potential to be conducive to introducing those with a more analytical and abstract way of thinking to musical concepts that they may otherwise have difficulty becoming acquainted with. This is in contrast to the original goal of the application which was to propose a way to teach and reinforce new concepts for those who already have some level of musical skill

through the lens of a more technical approach. Through continued development, I believe that *Relatable DAW* has the potential to accommodate both of these audiences effectively and gain a wider outreach than originally anticipated. To achieve this, I plan to continue to work on *Relatable DAW* personally following the completion of this interactive qualifying project as it is a concept that I am particularly interested in.

Chapter 5: User Manual

This final chapter serves as a manual to guide users in interacting with the application, clarify functionality, and answer anticipated frequently asked questions.

Section 1: Accessing the Application

1.1—Availability: At the time of writing this document, a live version of the application is hosted at https://relatable-daw.com. This URL is subject to change however, as I am unsure exactly how long I will keep it up and running following the completion of this interactive qualifying project. 1The most up-to-date information on the development of *Relatable DAW* and where to access it can be found on the GitHub repository that the application's source code is hosted on at https://github.com/lbodwell/Relatable-DAW.

Section 2: The Home Page

2.1—Authentication: A user must sign in with a Google account in order to save their compositions and make use of collaborative features. From the home page, simply click the "Sign in with Google" button and a popup window will prompt you to sign in using OAuth 2.0. From there, you will be able to access, edit, and share your saved projects and view or edit projects shared with you depending on the level of permissions you have been granted.
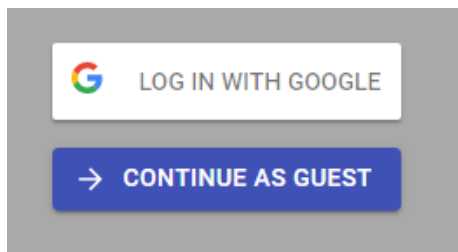
2.2—Guest Mode: If they choose not to sign in with a Google account, users can make use of the Guest Mode feature in order to test the functionality of the application in a sandbox-like environment. Pressing the "Continue as guest" button on the home page will redirect the user to this environment which is unable to interact with the central database or any other client.

2.3—The Project Manager: Once logged in, a user will be able to view all of the projects they have created as well as the projects that have been shared with them by others. Clicking a project will redirect the user to the main project viewer/editor. Projects owned by the user can also be deleted by clicking the trash icon.
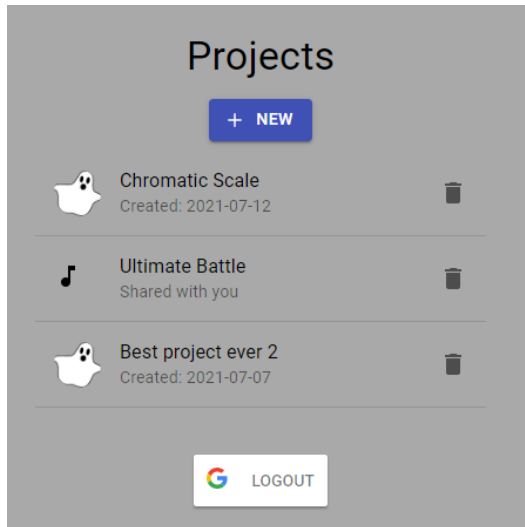

Section 3: The Options Panel

3.1—Options Panel Overview: The options panel is positioned horizontally above the sequencer and houses playback controls, key selection, volume and tempo sliders, and the share button.

3.2—Audio Playback: The play/pause button can be used to play and pause audio playback of the current note sequence. It will automatically loop back to the beginning of the sequence on completion. The stop button will pause and reset playback so that when it is resumed it will start from the beginning of the note sequence.

3.3—Choosing the Key: The key chosen from the dropdown in the options panel will be the default parent note and the only parent available to the first note placed on the sequencer. Every major key is selectable.
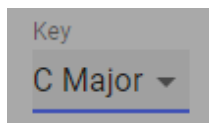
3.4—Changing the Synthesizer: There are four different synthesizer presets based on basic oscillator waveforms that can be chosen to be used for audio playback. By default, a sine wave is selected, but a triangle wave, square wave, and sawtooth wave are also available.
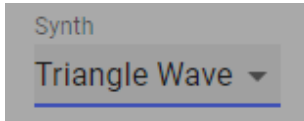
3.5—Adjusting BPM and Volume: There are two sliders in the options panel—one for controlling the BPM (beats per minute) and one for controlling the volume of the audio playback. The BPM slider is on a scale ranging from 60 BPM to 200 BPM and the volume slider is on a scale ranging from -32dB to 0dB.


3.6—Sharing Your Projects: To share a project or revoke access from current collaborators click the "Share" button and the Collaborators dialogue will open. To add a new collaborator, enter the email address of another user who has signed into *Relatable DAW* before. When a collaborator is added, your project will become available in the project manager on their home page. In order to revoke a collaborator's access, press the trash icon next to their name and email in the list. Other collaborators may manage access but cannot remove the owner of the project. In order to close the dialog, click anywhere outside of it or press the Escape key. This feature is not available in Guest Mode.
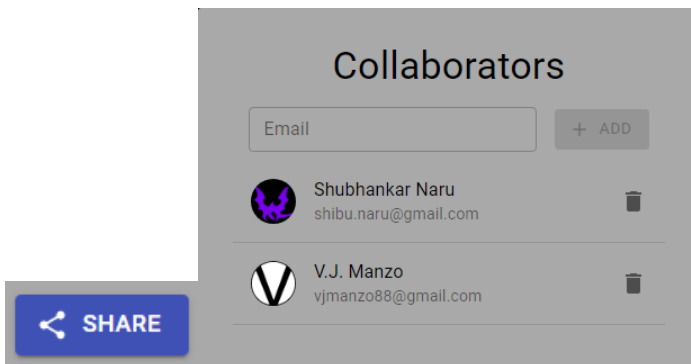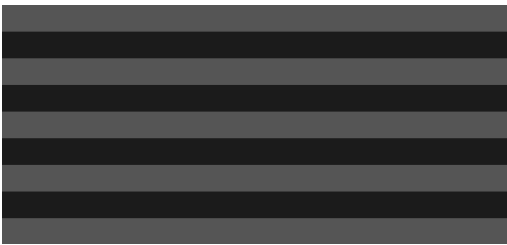
Section 4: The Sequencer

4.1—Sequencer Overview: The Sequencer is a visual representation of the note sequence defined by the relationships set in the Note Editor.
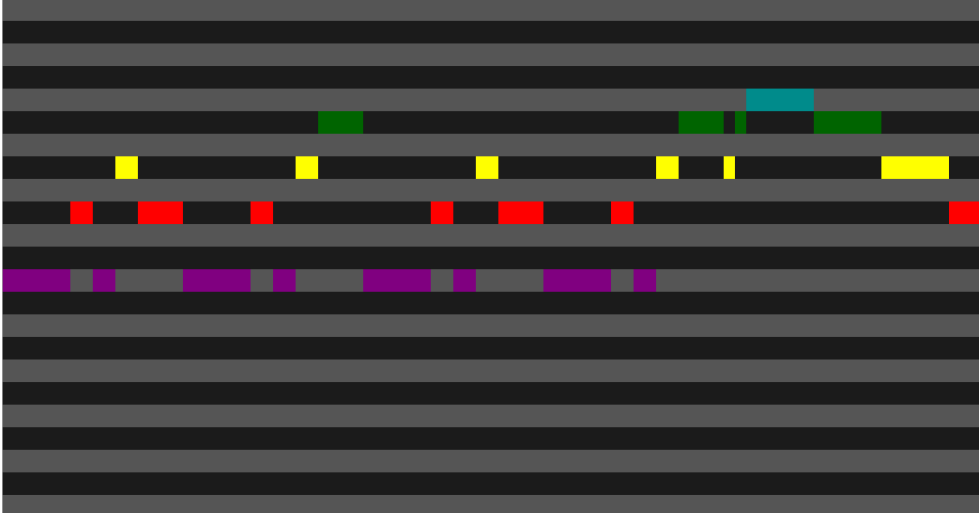
4.2—Note Layout: The Sequencer is a grid in which each row represents a different pitch spanning from C3-C6. The rows are marked by alternating tones of gray background colors. A note's vertical positioning indicates its pitch, and its horizontal positioning indicates its placement along the timeline of the note sequence. The note whose pitch is in unison with the tonic of the key will be marked red and the colors of the remaining 11 notes between the tonic and that same note raised up an octave is filled in by colors spanning the RGB color spectrum.

4.3—Navigation: Only a subsection of the Sequencer is displayed at a given time to prevent the application's content from overflowing past the viewport size. The sequencer can be scrolled vertically and panned in any direction by left clicking and dragging with the mouse away from the desired direction to move toward.

4.4—Selecting Notes: Clicking a note will select it, prompting the note editor to open in the sidebar. When a note is selected, an animated darkening effect will play in order to

help highlight it. To deselect the current note, click anywhere in the blank space of the Sequencer grid.

4.5—Collaborative Editing: Any users who have editing access to a project can join at the same time and collaboratively make changes. In order to prevent desynchronization issues, when one user makes a change, all other users are interrupted and the altered note is selected for everyone. This is not a perfect solution, but it prevents two users from making conflicting changes at the same time. Edits made to a project will be reflected in the Sequencer in real-time and are observable by all connected project collaborators, even those who only have viewing permission.

Section 5: The Sidebar

5.1—Sidebar Overview: The Sidebar is the section to the left of the sequencer and options panel features a project name editor when not in Guest Mode, and also houses the "Add Note" and "Clear Notes" buttons in addition to the Note Editor.

5.2—Changing the Project Name: The name of the current working project can be updated using the text field at the top of the side bar. Clicking off of the text field or pressing the enter key will save the project's name and it will be updated for all collaborators. The name change will also be reflected in the project manager on the home page of the project owner and all project collaborators. This feature is not available in Guest Mode.
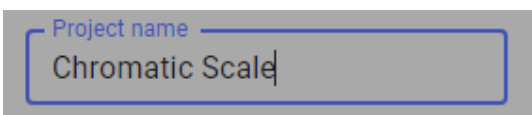
5.3—Adding Notes: "Clicking the "Add Note" button will add a new note to the end of note sequence. If no note is currently selected, the new note will be defined as a quarter note in unison with the tonic of the key with no delay. However, if another note is already selected, the new note's parent will be the currently selected note. When not in Guest Mode, this change will be reflected in the Sequencer for all collaborators.
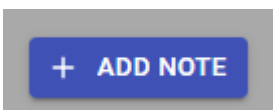
5.4—Clearing Notes: Clicking the "Clear Notes" button will remove all notes from the note sequence. When not in Guest Mode, this change is permanent and will be reflected in the Sequencer for all collaborators.
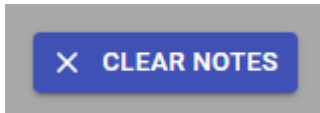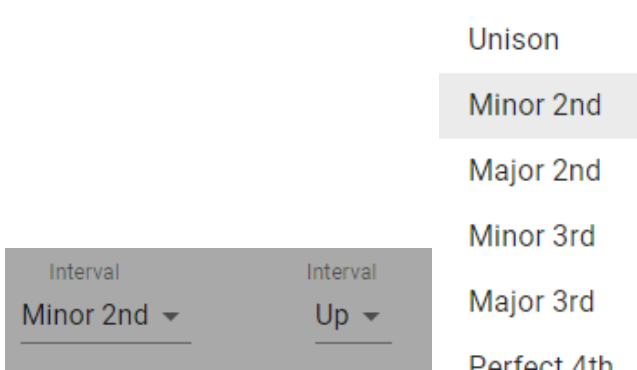

Section 6: The Note Editor

6.1—Note Editor Overview: The Note Editor is located within the sidebar and its contents are hidden when no note is selected. When expanded, the Note Editor displays the selected note's number in the note sequence and allows for configuration of the note's relation and timing. Altering any of the settings in the Note Editor constitutes an edit and when not in Guest Mode, this change will be reflected in the Sequencer for all collaborators.

6.2—The Parent Note Relation: Within the "Relation" section of the Note Editor, the parent note of the currently selected note can be chosen from the "Parent Note" dropdown. If the selected note is the first note in the sequence, the only available parent note is the tonic of the key. Otherwise, the selected note's parent note can be made any note that comes before it in the note sequence. The parent note acts as if it is a new local key center that the interval that determines the selected note's pitch is relative to. Because of this behavior, it becomes very easy to get outside of the original key even when unintended. This allows for some interesting things for experienced users to play around with, but beginners may choose to limit themselves to just using the tonic of the key as a parent note at first and expanding from there.
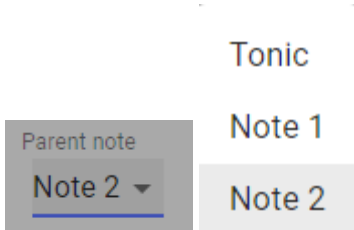
6.3—Intervals: Within the "Relation" section of the Note Editor, the "Interval" dropdown is used to define the relationship between the parent note and the selected note. All major, minor, and perfect intervals as well as the tritone are selectable. Using the "Direction" dropdown directly below, the direction of the interval can be changed between "Up" for an ascending interval and "Down" for a descending interval.

6.4—Durations and Delays: Within the "Timing" section of the Note Editor, the "Duration" dropdown is used to select the length of the selected note. Currently, the available note durations are as follows: whole note, half note, quarter note, eighth note, sixteenth note, and all of their dotted variants. Similarly, the "Delay" dropdown is used to create a delay of a given length between the previous note in the note sequence and the selected note. All of the same options that are available for the "Duration" dropdown are also available in the "Delay" dropdown, in addition to the default option of no delay, "None".
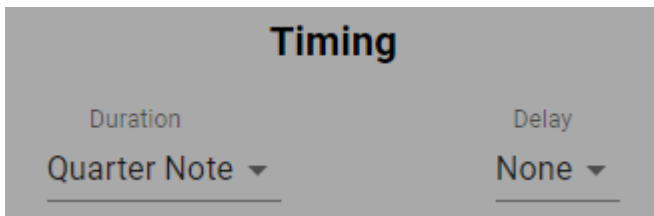
6.5—Deleting Notes: Clicking the "Delete Note" button at the bottom of the Note Editor will remove the selected note from the note sequence as well as any notes that depend on it. This includes notes whose parent note's parent is the selected note and so on recursively. When not in Guest Mode, this change is permanent and will be reflected in the Sequencer for all collaborators.
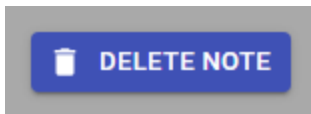
Appendix A: Maine State Music Standards

        The following excerpts are adapted from the *2007 Maine Learning Results: Parameters for Essential Instruction* and modified for relevance, readability, and formatting. An unedited copy of these standards can be found on the Maine Department of Education's website here: https://www.maine.gov/doe/sites/maine.gov.doe/files/inline-files/music-standards.rtf

A. Disciplinary Literacy – Music: Students show literacy in the discipline by understanding and demonstrating concepts, skills, terminology, and processes.

A1. Music Difficulty

9-Diploma
Students perform music that requires well-developed *technical skills,* attention to phrasing and interpretation, and the ability to perform various *meters* and rhythms in a variety of keys while modeling proper posture and *technique,* alone or with others.

A2. Notation and Terminology

9-Diploma
Students apply accumulated knowledge of musical notation, symbols, and terminology to perform music with greater complexity and variation including sudden *dynamic* contrasts.

A3. Listening and Describing

9-Diploma
Students listen to, analyze, and evaluate music using their understanding of pitch, rhythm, tempo, *dynamics, form, timbre*, texture, harmony, style, *and compound meter*.

B. Creation, Performance, and Expression – Music: Students create, perform, and express through the art discipline.

B1. Style/Genre

9-Diploma
Students perform music of various styles and *genres* that requires well-developed *technical skills*, attention to phrasing and interpretation and various *meters* and rhythms in a variety of keys, accurately applying the accumulated knowledge and skills of: proper posture and *technique*; musical notation; symbols; and terminology.

B2. Composition

9-Diploma
Students analyze and evaluate musical ideas expressed in their own *compositions* or the *compositions* of others.

Appendix B: Interview Protocol

       The following is an exhaustive list of the questions asked to Jake Sturtevant, a band director at Falmouth High School, and his answers to them. The majority of the questions were asked prior to the demonstration of an early version of *Relatable DAW*, but some of the later questions addressed his reactions to the application. The point at which this demonstration occurred is marked in the interview protocol.

Do you think the Maine state music standards are an accurate representation of what should be taught in a high school band class?

       "Yeah, so it's a loaded question because it really deals with focusing on how the music standards are written in the state of Maine. As of right now, there is a cohort that's doing some work on amending the music standards for all arts disciplines. The standards in some capacity, and I know that this probably doesn't really answer your question quite yet, but the standards are not really written in a way to reflect the skills that students should be able to meet and obtain. So that's the reason that they do need to be amended. With that being said, there's a lot of good in the context of what is expected of students based on the Maine learning results. I typically use a hybrid of the national music standards with the Maine state learning results in order to sort of reflect and represent what students should be able to do for skills at the high school level. As a result of that, in some capacity, yes, the Maine state music standards are an accurate representation, but in other results, the way that they're worded doesn't really reflect the skills needed, so some of them needed to be amended and hopefully that's what the cohort is working on."

To what degree do the Maine state music standards inform your lesson plans? Do you teach concepts not covered in these standards, or perhaps focus more on some areas than others? Are you limited in any way by these standards?

       "Yeah, so I would say they are a good representation of what I teach for content. I've just been able to hone them in a little bit more on the skills that students should be learning, and that that has come with a little bit of time and effort on my part, and other colleagues' parts to be able to change the wording of some of those skills."

Are there any additional guidelines (official or otherwise) you make use of in planning your curriculum?

       "Yeah, definitely the national standards and the Maine state learning results. A lot of being able to see other colleagues work, and what other colleagues are doing also is helpful—so professional development in any case. Through workshops and other conferences, I certainly pick up a lot of things to help plan my curriculum."

How important do you feel composition is to the high school band experience?

"Yeah, it's an intriguing question, because if you know my background a little bit, I actually come from a composition background. I did a master's in composition, so a lot of what I have for experience is compositional, so I really wanted to have my students, no matter what grade level I was teaching, experience composition in some capacity. I also think it's really useful to be able to understand music at a much deeper level when working compositionally or even arranging. I mean, you went through the program at Falmouth and kind of participated in the arranging project that I typically do with students also. I think arranging is just as beneficial for students to go through that process as a composition, so I would consider the arranging project that I do a compositional-based experience for students as well. So, I think it's a very important aspect for students to get out of the high school band experience. I don't think it's a central experience that students need to have. I think that there's a wealth and breadth of other experiences through performance-based activities that we do at the high school level to help students get the full breadth of what needs to be experienced at a high school band experience."

How important do you feel music theory concepts like scale degrees, intervals, and basic chord structures are to the high school band experience?

"So, sort of like I was talking about with composition it's not a central facet. It's important in some capacity to help students understand sort of the underpinnings and how music works. So, the theoretical concepts, I try to integrate into compositional practices in some capacity in the high school band experience, so that students will be able to understand these are the building blocks that music is built on in some capacity. So, it's not a central, but certainly an important aspect of that experience as well."

How many of your students relative to the total size of the class are interested in going beyond the basic requirements of concert band and pursuing musical concepts like theory and composition?

"I typically will ask, in an end-of-year survey and a beginning-of-year survey, students' interest levels and what people are interested in. I get a rough estimate back of about 10% or so, I would guess, are interested in moving beyond some of the concepts that we cover in class and really enjoy understanding the theoretical and the composition of components. Many times I'll guide those students to be taking theory-based classes and/or my songwriting class, to go beyond the concepts that we would do in the high school band experience. There's also definitely an overlap between being in multiple ensembles. I've had quite a few students that are both with me and in the choral program, be able to want to kind of dive deeper, and quite a few students who are involved in both jazz band and concert band that have certainly wanted to dive deeper. It's typically your students who are very passionate about music that will kind of want to take it to that next level and focus on the theoretical concepts and compositional aspects."

What role does technology play in your high school band class? Do you make use of any digital tools to aid in student learning? If so, which tools do you find to be most effective?

"In the context of a typical band classroom, I think a lot of what I've used in the past, for technology aids, have been sort of surrounding sight reading. I've utilized sight reading factory which has worked well. I have used SmartMusic in the past for students, so there have been some technology aides like that to help with repertoire and sight reading. I've certainly utilized different theory websites—musictheory.net is a great one. I use Theta Music Trainer in some of my other classes, which is a great web-based platform to be able to learn and work with ear-training and other aspects like that. So there are definitely some components of web-based and technology-related platforms that I've used in the past to teach and reinforce theory and some compositional aspects as well. In compositional aspects, I think that you might be aware that I've used recording platforms like GarageBand, which is a good one for doing some work with film scoring projects that I've done in the past. There's a great web platform that I've been using the last couple of years, Soundtrap, which is another good web-based recording platform that is useful in performance-based settings as well like this. So, there are definitely some good technology tools that I have used in the past for sure. I think that the most effective ones are the ones that sort of reinforce, but also kind of bring students in at a level that intrigues them. So some aspects of gaming, I think are important sometimes, because there's a lot of students who are kind of akin to that understanding from a gaming perspective and competition, and those sorts of aspects are helpful in some capacity to sort of rope students in. Other things are like intriguing sounds. Being able to manipulate sounds in a way that's not too challenging to understand the interface I think brings students in quite a bit as well."

How has COVID-19 affected the way you conduct your band classes? Has it led to an increased focus on theory, composition, etc. and/or an increase in the use of digital tools due to the difficulty of having many people playing instruments gathered in a small area?

"A lot of what I did with the COVID-19 year was to do some hybrid work. We did a lot of work utilizing Google Classroom and hyper docs that I put together for the students. There was an extended unit in the middle of the year that I did on my typical arranging project. In this case, what we utilized were components of just understanding basic theory concepts through YouTube videos. YouTube videos were very helpful. Other web-based platforms, like musictheory.net, and other ear training platforms, like Theta Music Trainer, I used quite a bit for students to kind of deal with the concepts that I was teaching in class with their arranging project. Then, there were also some notation-based platforms. We used NoteFlight to be able to do some work with notating parts as well, and that worked somewhat effectively. There were some issues with that, to try to figure out how to share it and how to be in the same document to do some work with that, but overall, it was pretty effective to be able to do some work with notation and understanding that concept also."

If you have made any significant changes to your curriculum due to COVID-19, do you foresee any of them remaining in effect after the pandemic?

"Yeah, definitely the use of hyper docs was important to kind of understand where we're going, to share helpful and useful information, and to have students develop an understanding and awareness of the concepts at a slightly more in-depth level than they would have in class. So yes, in some capacity, I will be utilizing those hyper docs that I put together this past year in the future for curriculum work. I would say not a significant amount of outside-of-class work will be continuing. That was really a challenge for students to work with the remote learning in some capacity. So, I'll probably include some of those hyper docs and that work in the context of the course itself in the classroom setting, but most likely, we'll be really focusing back in, especially this next year, on a lot of the performance-based stuff, which I felt like we just didn't have time for and weren't able to get to in the hybrid situation."

What are your thoughts on the usefulness of a web-based tool that would enable students to compose songs using intervals to define every note (instead of using sheet music notation, note names, or a grid with corresponding piano keys, every note's pitch is related to either the tonic of the key or another note preceding it)?

"Yeah, it's intriguing. In some capacity, one of the things that you're doing in the context of teaching students to compose is to utilize an awareness of both subjectivity and objectivity of what they're hearing and what they want to compose. So, I think I would have a lot of questions about this and want to see it more in action. One of the cautions that I might have about a program like this would be to ensure that students do have some element of subjectivity so that they're able to utilize their ears to be able to say, 'yeah, I like that,' or 'no, I don't like that,' rather than sort of thinking about it as more theoretical-based like, 'this interval is going to sound really good after this one, because of how this interval works.' Just being able to go compose something based on theory is going to, in some capacity, hone in on particular skills that are related to theory, but it's not always going to allow for students' creativity to thrive in the capacity of them being able to be aware of what is sounding good, what they like, and how they can make it move into a new direction and be part of that sort of subjective experience of composing on your own."

[Application Demo]

What is your initial reaction to the application? Do you expect high school students to find it fun and interactive but also educational?

"Yeah, I do think that's really important, and I know that this makes a lot of work for you, but the visual understanding, the representation, the interactive quality of what they're seeing in the interface itself, is usually really a predictor of how intriguing it's going to be to students. So, the more that you can do to sort of have that visual element there for students to be able to interact with, the better."

Do you think the act of creating something tangible will help students to understand the usefulness of music theory concepts by way of composition? Do you think some students may get more out of it than others?

"Yeah, so, I think it really depends on how it's built, and how it will utilize whatever skills that students are learning in the context of the interface. So, if I'm teaching about intervallic relationships, and melody contours, for instance, in the context of a lesson, then I would want students to be able to play around with an interface that would be able to do the skills that I was teaching in some capacity. If they're just going through and just kind of randomly selecting intervals to put in whatever order that they want to and change the durations, and then they can go back and tweak things based on what they heard, there's going to be some good things that come of that, but much more can happen when there's a particular given skill that's being taught that then they have an application where they can go play around with that."

Does the application seem easy and intuitive to use? How do you think musical ability will affect the user's experience with this application?

"I think a lot of the intuitive piece is going to be about the UI. Whether or not it's going to be more intriguing by those people with higher musical ability, that's a given. I think that typically in an interface like this, or any other interface, if somebody is really intrigued by the subject area, and they like playing around with it already, then that's going to go hand-in-hand with how much they're going to get out of it."

Do you think features enabling collaboration between students on this tool would be beneficial (live multi-user editing like Google Docs, saving and sharing compositions with others, etc.)?

"Yeah, I think eventually. If the purpose of it is to be compositionally based and to allow for students to be able to do some composition on their own utilizing technology, then sharing in any capacity is really important, because they're going to want to share that with other people. Whether it's just an export of a MIDI file that they can send to each other, or an actual online collaborative environment that they can both use to compose together in the same environment, I think either would be fine."

Do you have any feedback on the overall experience of the application? Are there any improvements that you feel could be made to its core features?

"I think most of it is interfacing and visual UI that I think needs to be focused in on. I do think, you kind of thinking through sort of the, 'what is it that you want students to be getting out of this?' is really important. If you want them to truly be doing some work with compositional skills surrounding intervallic relationships, I might kind of guide you towards thinking about understanding melodic things in general. So, understanding how teachers are going to talk about melodic contour, and phrasing, and how can you build in features that are going to be akin to teaching some of those skills in the context of the interface that you have going on?"

Do you have any additional thoughts you would like to share on the use of digital interactive media to aid in understanding of musical concepts in a high school band setting?

"Yeah, I mean, I think I've touched on a lot of them, and I'll certainly send you some resources. A lot of what I what I have been intrigued by, within the context of utilizing technology to teach particular concepts is the visual nature of it. Just being able to see it structurally laid out has been really helpful. I mentioned Hooktheory—I think that's a great one to check out. There are definitely some other web-based platforms that I think are worth checking out to be able to see what sorts of things are working well, and why people would go to those places. The Theta Music Trainer I use pretty often is kind of a fun place to go to as well. So, I'll send you a couple of them for you to check out, but a lot of them are really just visually engaging, they're interactive, and they allow for students to be learning concepts in a unique and different way than they would be in an in-person setting."