Principles in music composition pedagogy and their application in new technology to be used with young students.

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October 1, 2015

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Statement of Purpose

Music composition provides young children with an opportunity to express their creative capacity. The purpose of this empirical research study is to identify successful principles and teaching methods for music composition pedagogy, to implement these tenets in a piece of newly designed software, and to evaluate how the software can be utilized in teaching music to students in elementary school.

Rationale

As stated by Sir Ken Robinson, "My contention is that creativity now is as important in education as literacy, and we should treat it with the same status" ("Ken Robinson Says Schools Kill Creativity"). Creativity plays a huge role in the success of our society and individuals. Consequently, creativity should be instilled in students and developed by schools. To that end, music education provides an excellent avenue for student creativity through student-centered music composition.

As an elementary music teacher, I aim to make music composition a large piece of instruction and make music composition activities in my classroom an enriching process. I often utilize technology in student-centered music education, and it is my aim to develop a piece of software grounded in research that would facilitate the music compositional process as well as making it an engaging activity.

This study will begin by describing research on various methods and principles related to fostering the music composition process. Grounded in this research, a piece of software will be developed for the purposes of facilitating music composition amongst young children. After the software has been created, its effectiveness will be evaluated by having music teachers test the software and complete a survey concerning the software's value and potential uses in the classroom.

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Chapter 1: Innovation in Education

Creativity in the classroom is often viewed as a nice addition to instruction, but supplemental at best. However, invoking creativity and inviting students to think with more depth should be the cornerstone for pedagogy.

Creativity has some broad-reaching implications. Robinson states, “people associate creativity with the arts only...creativity is really a function of everything we do. So education for creativity is about the whole curriculum, not just part of it” (Azzam). Ultimately, problem solving can be applied to almost every domain. For instance, “if you're a creative chef, for example, then your originality is going to be judged in terms of cuisine” (Azzam). Creativity can be thought of as problem solving. Gould defines music composition as, “creating concepts – musical ideas that are produced in response to lived compositional problems. As these musical ideas develop, they create other compositional problems requiring related musical ideas to solve” (198). Czikszentmihalyi and Getzels state that creative accomplishment arises from “a problem-finding attitude” (Barrett and Gromko 214), and, Amabile suggests teaching various methods of problem solving as a means of creativity. Supporting creativity is also important for motivation in the classroom. Bronson states, “when creative children have a supportive teacher...they tend to excel. When they don't, they tend to underperform and drop out of high school or don't finish college at high rates” (Bronson). Often these students drop out because they become bored or discouraged (Bronson).

Supporting creativity in the classroom also better supports multimodal teaching. Reimer recommends that music education should educate all multiple intelligences of children utilizing, “applied creative thinking” (Guderian 6).

Sternberg's triarchic theory of intelligence suggests three distinct intellectual abilities: analytic, creative, and practical (Howard 49). In this theory, analytic abilities refer to the ability to "analyze, evaluate, explain, and compare or contrast" (Howard 49). Practical abilities refer to the ability to properly apply problem-solving skills to problems (Howard 49). In traditional instruction, students with strong analytic abilities tend to excel because of the fact-based memorization that typically occurs (Howard 50). Students are not typically reinforced in their creative and practical abilities in this form of instruction (Howard 50). According to the study done by the NASA Classroom of the Future project, students with high practical abilities and those with high creative abilities benefited from instruction where students were asked to creatively devise a solution to an authentic problem (Howard 64).

In addition to multimodal educational aspects, the utilization of music composition, specifically as a process of creation, fits Bloom's Taxonomy of Learning Domains. Bloom's Taxonomy includes remembering, understanding, applying, analyzing, evaluating, and creating (Armstrong). All of these skills are necessary and utilized as a part of the music composition process (Guderian 7). Accordingly, creating is central to the National Core Music Standards ("Standards").

Students can engage in knowledge building while creating. Many teachers might avoid taking time for creative work and composition in the classroom as they might think those activities would take time away from instruction. However, according to Bronson, it is still possible to meet curriculum standards if taught appropriately. In an experiment done with 5th grade band, the experimental group of students was given creative ways of learning including composition and improvisation assignments (Guderian 8). The control group was solely given assignments of practice and review (Guderian 8). Despite having the same amount of

instructional time in both groups, the experimental group dramatically outperformed the control group (Guderian 8). Torrance, who did a great deal of research in creativity, explains that while children participate in creative activities, they can indirectly learn a great deal about the subject matter (Auh 1). For instance, in the process of writing a melody, students need to learn notation conventions to notate it on the music staff. The Scottish education system reflects this view. In Scottish education, composition is central to the music curriculum and viewed as a way to enhance listening and performing (Macdonald 293). Getzels and Csikszentmihalyi found that creative solutions discovered by the problem solver are of more significance to the solver aiding in the process of recollecting information (Carter 558). According to Guderian, "applied creative assignments that are an outgrowth of listening experiences and are related to other aspects of the course content, and to subject areas in the school curriculum outside of music class, make sense to students and reinforce the concepts under study" (Guderian 11), and ultimately, "you can't do what you want to do—make music—unless you have the wherewithal to do so." (Guderian 7)

Ultimately, creation in the music classroom has broad-reaching merit in its own right. According to Kaschub, engaging in music composition allows students to engage in a process that parallels the human experience in many ways. It allows students to engage in "the joys of problem solving, self-expression, and learning in music" (Guderian 13). Teaching composition is not ultimately about molding someone into the next Beethoven, but allowing students to immerse themselves in a music-making experience (Kaschub).

Chapter 2: Creativity Outside the Classroom

Plucker, a professor of Education Psychology at Indiana University, visited China and was impressed with how students were challenged with creative problem solving in the education system. In speaking to faculty in China, he described the trend of national standardized testing in the United States and the necessary rote memorization to prepare for these tests. “After my answer was translated, they just started laughing out loud...They said, 'You're racing toward our old model. But we're racing toward your model, as fast as we can’" (Bronson).

China is only one example of governments across the world making creativity a priority. British secondary-school curricula in every subject were changed in 2008 to emphasize the generation of ideas (Bronson). The European Union designated 2009 as the European Year of Creativity and Innovation (Bronson). Throughout the year there were conferences in neuroscience as it related to creativity, and funding was allocated so that teachers could receive professional development in authentic problem-based learning programs (Bronson). Japan is also moving away from memorization-based education to "problem-solving-focused education" (Watanabe). Creativity is being valued more as its importance is recognized in social, business, science, and personal domains.

One reason for this increased attention is that the ability to approach creativity and problem-solving is important to the social-emotional needs of people. As Joseph D. Keating states, “we should see problems as opportunities that should be sought out. It is by finding and solving problems that we make our lives worthwhile through learning and accomplishment. Indeed, our lives are defined by the problems we find and solve.” (Carter 559). Getzels and Csikszentmihalyi suggest, “finding and solving problems are basic human needs, a way of controlling our environment” (Carter 559 - 560). It is a central part of our nature to seek out and

solve problems and expand our knowledge. In fact, people who are better at problem-finding and problem-solving have better relationships (Bronson). A study of 1,500 middle school students found that those with high "creative self-efficacy" had more confidence in their future and ability to succeed. (Bronson). Finally, an inability to find alternative approaches to problems, can lead to despair and potentially be a risk factor for suicide (Bronson).

Creativity is also central to our success in the future. As Professor Ken Robinson states, "nobody has a clue what the world's going to look like in five years, or even next year actually" (Azzam). In order to be prepared for the ever-changing world, people must be trained to think creatively and adapt. Torrance verified this concept through tasks used to assess creativity (Bronson). While Torrance's tasks were far from perfect in assessing creativity, kids who were more successful in these tasks were more likely to be, "entrepreneurs, inventors, college presidents, authors, doctors, diplomats, and software developers" (Bronson).

Beyond just the individual rewards, creativity benefits society as a whole. Society needs creative solutions to solve its social ills ranging from poverty to pollution. Solutions to problems, "emerge from a healthy marketplace of ideas, sustained by a populace constantly contributing original ideas and receptive to the ideas of others" (Bronson). NASA is investing in Classrooms of the Future, which in part, is seeking to develop the future's creative problem-solving scientists (Howard 51). In the business world, Fortune 500 companies are constantly looking for people who can be innovative (Azzam). As stated by Professor Teresa Amabile of the Harvard Business Review, "when creativity is killed, an organization loses a potent competitive weapon: new ideas." A poll of 1,500 IBM CEOs identified creativity as the most important aspect to "leadership competency" in the future (Bronson).

It is worth noting that while there are some very obvious places for creativity, the necessity for creativity can permeate some unsuspected facets as well. Amabile asked business managers to identify fields in which they would not want creativity (Amabile). A common answer was accounting, which might be viewed as a field of concrete numbers and little more (Amabile). However, as Amabile points out, activity-based accounting, which includes a different way of looking at costs, was an invention in accounting and has had a dramatic effect in the business world.

While creativity is a necessary skill for individuals and our society as a whole, it is under threat. Kyung Hee Kim analyzed Torrance's creativity task results for 300,000 students and adults and found that while IQ has consistently increased 10 points with every generation, creativity scores on Torrance's tasks started to decline starting in the 1990's (Bronson). According to Kim, "it is the scores of younger children in America--from kindergarten through sixth grade--for whom the decline is most serious" (Bronson). According to Ken Robinson, "At the moment, instead of promoting creativity, I think we're systematically educating it out of our kids" (Azzam). Bronson also suggests the number of hours kids play video games and watch TV instead of engaging in creative activities is a potential problem (Bronson). However, Bronson goes on to concur with Robinson's assessment saying that schools are often squashing creativity as curriculum standards leave little room for applied creativity (Bronson). Bronson goes on to say,

"While our creativity scores decline unchecked, the current national strategy for creativity consists of little more than praying for a Greek muse to drop by our houses. The problems we face now, and in the future, simply demand that we do more than just hope for inspiration to

strike. Fortunately, the science can help: we know the steps to lead that elusive muse right to our doors.” (Bronson)

Chapter 3: Nursing the Seed of Creativity

Before delving into means of promoting and fostering creativity, it is worth considering the meaning of creativity. Ausubel says, “creativity is one of the vaguest, most ambiguous, and most confused terms in psychology and education today.” (1). So, to properly determine how to develop creativity, it is necessary to define what is and what is not included in creativity. Russ defines a product of creativity as “(a) unique, original, novel, (b) good, that is, adaptive, useful, aesthetically pleasing, according to the standards of the particular discipline” (Auh 3). Bronson corroborates this definition by defining creativity as the, "production of something original and useful.” Most definitions of creativity in the literature seem to indicate that creativity includes aspects of usefulness and appropriateness in addition to its uniqueness.

As it pertains to music composition in particular, Macdonald similarly defines creativity in music as, “the creation of music that is new to the originator and that has come about through a process of experimentation, trial and error, sharing of musical ideas, collaborative work and that may or may not be written down in some form or other” (Macdonald 293). Ausubel expresses a similar sentiment saying that creativity includes sensitivity to existing problems, facility in formulating, testing, and reformulating hypothesis, skill in improving solutions, openness to new solutions, spontaneity, flexibility in solutions, perseverance, and venturesomeness (Ausubel 2).

It is worth noting that creativity is not something that should be taught per se. Current thinking suggests that people do not need to be *taught* how to be creative as people are naturally creative (Bronson). Livingston says that students present creativity in many aspects of their lives including, “the use of the Internet, various extracurricular pursuits, or even, occasionally, the

classroom." (59). So fostering creativity is not as much a matter of how to teach creativity as it is how to promote creativity already present in students (Livingston 61).

There are many personality traits that teachers can foster in students. Students who can face adversity and are persistent are much more likely to be successful in creative pursuits (Brinkman 48). It is important to persevere through potential dry spells and experimentation to arrive at a successful result (Amabile). A flexibility and breadth of thinking is also extremely important (Bronson). Creative people often are comfortable with disagreeing with people because they are trying to find solutions outside the conventional (Amabile). Creative people also have a high tolerance for ambiguity (Brinkman 48), often approach problems from many different angles combining knowledge from disparate fields (Amabile), have a wide range of interests (Brinkman 48), and value diversity of opinion (Azzam).

As far as general environmental influences, Bronson makes recommendations about how parents and teachers can promote creativity in their children. Parents and teachers can help foster creativity in their children by encouraging uniqueness but providing stability (Bronson). They need to be responsive to kids' needs, but challenge kids to develop skills (Bronson).

While there are some aspects of innate individual qualities involved in creativity, creativity can be improved through practice. "Think of it like basketball. Being tall does help to be a pro basketball player, but the rest of us can still get quite good at the sport through practice. In the same way, there are certain innate features of the brain that make some people naturally prone to divergent thinking. But convergent thinking and focused attention are necessary, too, and those require different neural gifts" (Bronson). Bronson continues by saying that the common denominator in programs aiming to teach creativity is that they quickly switch from intense divergent thinking to extreme convergent thinking (Bronson). While creativity training

takes time and many repetitions to develop (Livingston 59), studies conducted at the University of Oklahoma, the University of Georgia, and Taiwan's National Chengchi University independently confirm that creativity training can be effective (Bronson). Teachers can assist in developing divergent thinking by modeling techniques for generating ideas (Brinkman 48). Even the knowledge that creative people generate lots of ideas can lead to a student trying to develop that skill (Brinkman 49).

Bronson elaborates on the necessity for both convergent and divergent thinking by providing a glimpse into the mental processes involved in creativity. According to Bronson, at the start of the creative process, someone focuses on obvious facts to see if there are familiar solutions that would present an answer. After that, the brain engages in divergent thinking searching for memories that might be even somewhat pertinent. During this divergent thinking process, the brain looks for "unseen patterns, alternative meanings, and high-level abstractions" (Bronson). Ken Robinson suggests that skills of divergent thinking can be nurtured by encouraging the use of "analogies, metaphors, and visual thinking" (Azzam). The brain switches from this broad view of information in divergent thinking to extremely focused thinking necessary for convergent thinking (Bronson). The brain attempts to thread the pieces of information gathered during the divergent thinking process into a coherent idea (Bronson). Once the idea is formed, the idea is considered for value, and whether or not it is worth further pursuit (Bronson).

This description of the creative process is similar to Newell and Simon's concept of the problem space. As a part of the problem space model there is an initial state, goal state, and everything in the middle is "various intermediate positions or problem states in between" (Carter 552). The problem space includes all possible means of getting to the goal from the initial state

(Carter 552). As a part of this theory, the problems can evolve bouncing back and forth between starting to solve the problem and almost solving the problem as new discoveries are made (Carter 559). As an example, during the music composition process, someone might decide that the form of the piece should be ABA form with the B section in the key of the dominant. As the composition develops, the composer decides that the end of the A section would flow nicely into the relative minor key upending the original blueprint for the form.

A fundamental aspect of moving through the problem space and indeed, problem solving as a whole, is whether the problem is well-defined or ill-defined. A well-defined problem is a problem where all constraints are clearly defined. An ill-defined problem is not as clear concerning constraints. A key part of the problem-solving process is moving a problem from the ill-defined state to the well-defined state (Carter 553). Success in solving problems is dependent on how well the goal state is defined (Carter 553). Consequentially, constraints help to define what the solution will look like (Carter 554). So a problem where all constraints are defined can be considered half solved (Carter 554). As an example, if someone is looking to solve a Sudoku puzzle, it is much easier to solve the puzzle if all but one of the numbers are determined as opposed to a puzzle where there might only be five numbers given. So a teacher asking productive questions can be extremely important because "formulating the problem may be a more important accomplishment than achieving the solution once the productive problem has been formulated" (Barrett and Gromko 214).

This aspect of well-defined problems relates directly to pedagogy for the creative process. While an open problem of "write a melody" may be liberating for some students, it could potentially be crippling for others as there is a multitude of potential options to consider. On the other side of the spectrum, a problem like, "write a melody that only contains quarter

notes on G4 all played by a flute in the same manner" is constraining to the point that there is no creativity allowed. A good middle ground like, "create an eight measure melody using notes from the C pentatonic scale" could provide enough bounds to make the problem feel more manageable, but not strict. Thus, some constraints might allow a certain amount of safety and better direct where a solution might go.

Another important aspect of creativity is collaboration. Barrett and Gromko state that, "creative artists are not born, but are made within social communities where members practice problem finding, problem solving and productive evaluation." (227). Ken Robinson states, "most original thinking comes through collaboration and through the stimulation of other people's ideas. Nobody lives in a vacuum. Even people who live on their own—like the solitary poets or solo inventors in their garages—draw from the cultures they're a part of, from the influence of other people's minds and achievements." (Azzam).

There are several factors that improve this collaborative creative process. Groups with various backgrounds, experience, and opinions allow for different expertise and thinking styles (Amabile). In a heterogeneous group, "ideas often combine and combust in exciting and useful ways." (Amabile). Amabile identifies the following key features of group interaction. Members in the group share excitement over the team's goal (Amabile). There is a willingness to help each other and persist through difficult aspects of the project (Amabile). Amabile advises that group members should recognize the unique skill set that each member brings to the table (Amabile). Finally, group members should bring their enthusiasm to the table because excitement can be contagious in group settings (Amabile). Brinkman recommends minimizing group conflicts as much as possible as "Infighting, politicking, and gossip...take peoples' attention away from

work" (48). Similarly, Macdonald found that projects created by friends were usually better than projects created by acquaintances because communication is usually better (295).

Beyond collaboration, proper individual motivation is supremely important in the creative process. Without proper motivation, students will not be able to focus on the problem at hand nor generate good solutions to the problem (Amabile). To those ends, as much as possible, students should be in Csikszentmihalyi's concept of flow to maximize creativity. Bronson states that, "In the space between anxiety and boredom was where creativity flourished." From Macdonald's study concerning flow as it relates to music composition, students in a state of flow strongly correlated to better creativity in music composition (300). In order to create tasks to optimize flow, Macdonald makes the following recommendations. Activities should be designed in such a way that there is no worry of failure (300). These activities should have clear goals and should receive timely feedback, whether it be through peer mentoring, teacher discussion, or personal reflective discussion (Macdonald 300). Finally, the challenge of the activity should not overwhelm students, but should balance challenge and skill (Macdonald 295).

Finding the proper intrinsic motivator is also essential to proper motivation. Amabile finds that intrinsic motivation is vastly superior to extrinsic motivation stating, "A cash reward can't magically prompt people to find their work interesting if in their hearts they feel it is dull" (Amabile). In fact, Amabile found so much evidence supporting the necessity of intrinsic motivation that she created the "Intrinsic Motivation Principle of Creativity" (Amabile). To convey the reason for why intrinsic motivation matters so much, Amabile gives the following explanation as it relates to exiting a maze, saying someone, "might actually find the process of wandering around the different paths—the challenge and exploration itself— fun and intriguing. No doubt, this journey will take longer and include mistakes, because any maze—any truly

complex problem—has many more dead ends than exits. But when the intrinsically motivated person finally does find a way out of the maze—a solution—it very likely will be more interesting than the rote algorithm. It will be more creative." (Amabile). Nobel-prize winning physicist Arthur Schawlow echoes this sentiment saying, "The labor-of-love aspect is important. The most successful scientists often are not the most talented, but the ones who are just impelled by curiosity. They've got to know what the answer is." (Amabile).

Students also need the proper encouragement and support throughout the creative process as well. Students should receive timely praise for accomplishments and creativity (Amabile). Throughout this process, students should feel free to proceed down paths that might not work because it is not possible to know what ideas will fail and what ideas will work from the onset (Amabile).

There are several theories as to the stages involved in the creative process. Graham Wallas's Stages of Compositions includes the four stages of preparation, incubation, illumination, and verification (Gall and Breeze 2). Webster's "Model of Creative Thinking Process in Music," includes the four stages of preparation, time away, working through, and verification (Gall and Breeze 2). The new thinking model, ORIENT, based on ideas by Dewey and Wallas, includes the following aspects (MacDonald 294). The first aspect of the ORIENT model is where options (O) are identified. The next area is dedicated to review, revisions, and reflection (R). The third feature is dedicated to interim evaluation (IE). The final aspect in the ORIENT process is where new thoughts are generated (T). In the ORIENT model, these different facets can occur at any time.

A common thread in all of these theoretical frameworks is that there are multiple phases to the creative process and also that the creative process takes time to move through those

phrases. Time is required for the incubation process (Brinkman 48). Time away from creative tasks can allow for ideas to develop unconsciously (Amabile). Students need to have enough time to complete the project at hand but not too much (Amabile). Also, any time constraints imposed on the creative process need to be authentic (Amabile). An example might be that a piece needs to be composed prior to the next concert.

Beyond being given the freedom of time, students need to be given the freedom to explore. Brinkman suggests leaving room for unplanned and unpredictable goals to occur (49). As long as students are working within the established parameters of the assignment, students should feel free to diverge from conventional thinking (Amabile). In terms of the business world, Amabile states that, “creativity thrives when managers let people decide how to climb a mountain; they needn’t, however, let employees choose which one” (Amabile). Ken Robinson suggests, “encourage kids to experiment, to innovate, not giving them all the answers but giving them the tools they need to find out what the answers might be or to explore new avenues” (Azzam). As a part of this process, some students may need space to create so they do not feel interrogated about the project on which they are working (Barrett and Gromko 224). This freedom to create can be liberating and can create an ownership over the process. This freedom gives people ownership over the process increasing their motivation (Amabile). In the exercising of divergent thinking many ideas might be inappropriate or not useful, but this is part of the process of thinking divergently which is central to creativity (Brinkman 49).

This freedom in creativity is also important to the actual medium as well. Robinson says, “A big part of being creative is looking for new ways of doing things within whatever activity you're involved in. If you're a creative chef, for example, then your originality is going to be judged in terms of cuisine. There's no point applying the criteria of modern jazz to somebody

who's trying to create a new soufflé" (Azzam). A study was conducted giving creative engineering tasks to engineering majors and creative music tasks to music majors (Bronson). Inside the brains of these participants, the same activity occurred (Bronson). Both groups of participants were generating and evaluating ideas in real time (Bronson). Azzam recommends that someone should be creative in the medium for which they have personal aptitude. Webster's research confirms this recommendation, as the single best predictor for musical creativity was musical achievement (Auh 2). According to Guilford's structure of intellect, there are about 120 distinct cognitive abilities (Ausubel 3). So it is quite likely that individuals can become "a genius or near-genius with respect to one or more of these abilities" (Ausubel 3).

In the classroom, there will be times that the medium for creativity will have to be predetermined. For instance, it might not be reasonable for students to make a drawing when they should be writing a music composition. However, it is worth noting that in Scottish education, nothing is studied in isolation. In Scottish curriculum, one element is always studied in reference to at least one other (Macdonald 293). "So, listening is usually studied with a view to better understanding the ways in which music is created, which in turn informs the performer's understanding of the musical demands of a piece of music." (Macdonald 293). So, while it might not be appropriate for students to create a drawing instead of a music composition, it might be worth creating a drawing that elaborates the music composition in some manner.

Beyond the social-emotional needs involved in the creative process, there are several cognitive skills necessary. One key aspect to creativity is the ability to abstract concepts out of creative works (Goldman 36-37). In a paper, this might mean abstracting out the main ideas. In a composition, this could refer to identifying a melody from a sequence of notes. In order to transform a work or the elements present in a work, abstraction allows for analogy from one type

of problem to another (Goldman 36-37). Archambault defines an aspect of creativity as the ability to, “find recognition of meaning in a given material...a meaning which is not predictable from a mere examination of the elements presented - and the translation of this meaning into an ordered product” (191). As an example of this process, it is impossible to embellish a melody without first being able to identify the abstract concept of a melody from a series of notes. The composer and teacher from Barrett and Gromko’s case study seeks to help composition students in this process by talking students through their abstractions. When a student had not thought through a passage in a composition, the teacher describes what has occurred in the piece so that the student could contextualize what has occurred in the composition (Barrett and Gromko 220). With that context, the composition student is able to refine the ill-defined passage by better relating the passage to what has occurred in the composition up until that point (Barrett and Gromko 220).

Important to this abstraction process as well as the creative process as a whole is some level of mastery over content knowledge. Barrett and Gromko go as far as to say that it can take about ten years before someone has enough subject knowledge to add a creative contribution within a particular domain (Barrett 213). While this refers to some pivotal shifts of music as a whole, like Beethoven’s ushering in of the Romantic Era of music, this does also apply to creativity on a smaller scale as well. Csikszentmihalyi states, “a genuinely creative accomplishment is almost never the result of a sudden insight, a light-bulb flashing on in the dark, but comes after years of hard work” (Barrett and Gromko 214). A study conducted by Auh found that the most significant factors in creativity in music composition included musical experience and musical achievement (Auh 6). In a case study examining the teaching of composition, the beginning of composition lessons necessitated some more foundational content

knowledge like technical correctness and later moved to more nuanced musical knowledge such as creating a musically coherent piece (Barrett and Gromko 218 - 219). Throughout these composition lessons, the creative process required research in the form of listening to lots of music in order to develop a repertoire of ideas (Barrett and Gromko 224). Ultimately, according to the composition teacher from Barrett and Gromko's case study, much of music composition is the technical side of things rather than innovative side (226).

Herb Simon describes this content knowledge in the creative process as a "network of possible wanderings" where the larger the base of the knowledge, the more avenues there are to pursue (Amabile). Another possible way of looking at this mastery of content knowledge is that it allows people to think less about the technical side of things leaving more cognitive resources to pursue the creative aspects (Azzam). Daniel Ansari, neuroscientist at University of Western Ontario, and Aaron Berkowitz, at Harvard University, studied music cognition by putting Dartmouth music majors and non-musicians in fMRI scanners and letting them improvise melodies on a fiber-optic keyboard (Bronson). Highly trained individuals are able to focus on the task in front of them and deactivate their right-temporoparietal junction which is in charge of interpreting incoming stimuli (Bronson). This allows for extra focus, which in turn allows for creating music more spontaneously (Bronson). This study was corroborated by Charles Limb of John Hopkins with Jazz Musicians (Bronson). Current thinking suggests this phenomenon could also be true for dancers, speakers, comedians, and athletes who improvise in games (Bronson).

Students can be encouraged in this process of attaining content knowledge. Bronson recommends that students research answers rather than being given answers (Bronson). Bronson continues arguing that by middle school many students lose motivation and engagement at school because middle school students have stopped asking questions and stopped seeking out

learning opportunities (Bronson). The Testing Educational Theory through Educational Practice framework utilized as a part of NASA's Classroom of the Future program supports this argument placing great emphasis on piquing students' curiosity in initial stages (Howard 67).

Content knowledge provides the right building blocks for the creative process, and having the right pieces is central to creativity. Merriam-Webster defines composition as "the combination of parts or elements that make up something" ("Composition"), and this process of combining elements to form new pieces is a consistent theme in the literature. As a means of approaching composition, Guderian suggests students could create a composition with a beginning, middle, and end where the middle part contrasts the beginning and end (10). This idea provides, "an open-ended framework for the decision-making and organizing process of composing." (Guderian 10). Deleuze and Guattari define the creative process as "creating, arranging, and rearranging perspectives" (Gould 197). Not having the proper building blocks to create can hinder the creative process. Gick and Holyoak note that pieces that serve as "distractor" information hinder the recall of appropriate analogies and abstraction necessary for the creative process (Goldman 36-37).

Chapter 4: Specific Musical and Technological Considerations

Music as a domain has some more specialized considerations as a part of the creative process. For instance, Auh analyzed creativity in music composition in the domains of craftsmanship, musical syntax, musical originality, musical sensitivity, and repetition of song (the song could be played more than once with the same result) (3). However, there are some themes and considerations that should be noted as a part of the music composition process.

Kaschub relates music closely to emotion due to music's temporal qualities (Kaschub). Neurobiologist, Damasio, says that human bodies possess the means of maintaining "biological homeostasis" (Kaschub). Damasio then defines emotion as, "some disturbance in the status quo of bodily state" (Kaschub). For instance, if someone has a pet that passes away, that is a change from the normal. That change in state is perceived with the emotion of grief. Music closely mirrors this emotional process. When a piece of music subverts our expectations or has an unclear direction, those changes cause us to perceive emotions of surprise or uneasiness. In this way, music allows us to explore emotions through our interpretation of sound (Kaschub).

There are also perspectives for framing the understanding of the compositional process as well. Schenker theorized that music was constructed with three layers occurring at the same time: the "ursatz" which is the background, the "mittelgrund" which is the middle ground, and the "vordergrund" which is the foreground (Kaschub). The background serves as a "fixed entity" by which changes are perceived (Kaschub). In Damasio's theory of emotion this background serves as a place to observe the, "juxtaposition of information in order to detect change" (Kaschub). Composers want listeners to hear changes. So in order to create some context in order to hear change, there has to be some sort of background or unifying element by which listeners can have some sort of anchor. Without that background, listeners are lost. (Kaschub).

The middle ground allows for the ability to make connections between the background and foreground (Kaschub). In Damasio's framework, the middle ground connects body experiences to consciousness (Kaschub). Middle ground in music either supports or denies expectations and is important for the emotive layer (Kaschub). In Schenker's view, musical items that draw our attention and are most memorable are in the foreground (Kaschub). Damasio would label the foreground as being consciousness and our conscious registering of an emotion (Kaschub). With both Schenker's view of music and Damasio view of emotion, meaning is being drawn through the interaction of these layers (Kaschub).

There are several themes that are present in the compositional process as well. A composition must appropriately balance change and stability. Listeners, almost unconsciously, try to predict what is coming in a composition, and changes invite curiosity (Kaschub). However, there needs to be stability in a piece of music, whether it be in the form of a tonal center, formal structure, rhythm, or defined length of silence (Kaschub). Without some stability, there is no context to detect change (Kaschub). Children's music in particular tends to be much more stable than unstable (Kaschub). Instability can be encouraged by expanding the definition of music (Kaschub). Periods of sound and relative silence often occur naturally and should be considered in composition (Kaschub). Unity and variety should be balanced as well (Kaschub). Leonard Meyer sees unity as a musical thread that the mind perceives. When this thread is dropped, or replaced, variety is achieved (Kaschub). Tension and release are a consistent theme in music composition (Kaschub). Veronika Cohen refers to "energy contours" of music, which could be seen as listeners moved responsively to music visualizing this tension and release (Kaschub). Finally motion and stasis should be balanced in a composition (Kaschub). Music, by its nature has elements of time in it as it is "directional, irreversible, and continuous" (Kaschub). Kaschub

notes that students who might find music to be boring usually do not perceive a notion of motion within a piece.

In many ways, technology can assist in the creative process. Technology can provide scaffolding for students in the compositional process bridging the gap between students' current abilities and the demands of the classroom activity (Howard 67). Gall and Breeze suggest that teachers should emphasize listening to make good artistic decisions during the compositional process, which is greatly assisted by computer audio playback (Gall and Breeze 12-13). This scaffolding process has been termed as the "democratisation of music" by researchers because composition is no longer something that can only be done by highly-trained musicians (Gall and Breeze 14).

Beyond using computer applications to assist in the compositional process, technology can support a more multimodal educational experience. Cope and Kalantzis found that audio is just one aspect of learning (Gall and Breeze 4). They defined the other modes of learning as linguistic, visual, gestural, and spatial (Gall and Breeze 4). These modes can work together in the educational process allowing for "transduction or transcoding between modes" (Gall and Breeze 4). Computers allow the same information to be presented in multiple modes assisting in the learning process. In fact, the music software, Cubasis and Cubase VST offer multiple views to interact with notation (Gall and Breeze 9). In addition, research shows that software can accommodate all three of Sternberg's triarchic strengths (Howard 66). Music software can present music in such a way that it matches how people listen to music. For instance, Van Leeuwen's three stage plan as it applies to how we perceive music is mirrored in how the software eJay presents music (Gall and Breeze 11).

While there are numerous educational advantages to using technology, computers allow for some interesting artistic choices as well. Technology can be used to subvert normal musical conventions. For instance, audio that is typically the accompaniment like the bass line of a song could become the melody (Gall and Breeze 4). Similarly, electronic music has its place in the canon in its own right. Luigi Russolo advocated for an “expansion of orchestral timbre” by allowing for sounds outside the typical orchestra such as machine and animal noises (Martin 122). Pierre Schaeffer created the practice of “Cinema for the Ears,” where everyday sounds could be the components for composition (Martin 123). Similarly, the composer R. Murray Schafer who first created the concept of “Soundscape," viewed it as “the total field of sounds wherever we are” (Martin 124). Ultimately, Martin argues, “although I would not disparage the importance of learning tonal music, I would argue for a broader perspective that includes the possibility of development and increasing sophistication with sound-based composition.” (Martin 127-128). This kind of expansion of the compositional repertoire is only possible through recording technology, which is greatly assisted by computer software.

While there are many things to be gained by the utilization of software in the creative process, there are factors of usability that must be considered. Norman advocates for technology that provides strong clues for how it should be used (Gall and Breeze 3). This has particular ramifications in the user interface. Simple and important functionality should be easily accessible in the software (Gall and Breeze 3). Finally, this user interface should provide strong clues as to its use based on past knowledge and our perception of things (Gall and Breeze 3). For instance, it is a convention that buttons with an “X” usually refer to cancelling an operation. So, new software should incorporate these conventions so that the user can draw on previous experience.

An easy to use program will allow for students to quickly communicate creative ideas before the ideas are lost (Gall and Breeze 10).

Chapter 5: Construction of Project

The aim of this project is to provide young students a means of tackling music composition so that it is easily approachable and adaptable to the students' needs. Music composition can be a daunting task. Without any aid, music composition requires a large base of prerequisite knowledge (e.g. harmony, rhythmic consistency, traditional music notation, etc.). This process can be effectively scaffolded with the use of computer software. Also, students learn in a multitude of different manners and come to form meaning in music in varying ways. Computers have the ability to display the same information in a multitude of different ways. So, the same piece of music can be visualized in many different ways to suit the learning mode of the individual student.

With this approachable and multimodal goal in mind, several requirements were developed. This program needed to be designed to be used on a variety of devices. So, the code was designed with the potential to be used as a web application, desktop application, or mobile device application. This suits both the best interest of the students and potential technological limitations imposed on music teachers. If this program can be used on a multitude of devices, students can choose the device and means that is best for them. Students could use the program while sitting at a computer or lying on the floor with a tablet. Also, teachers can use the program on the technology that they have in their classrooms. For instance, if a teacher only has access to a computer lab, then students can make use of the desktop application. If a teacher chooses to make use of a personal tablet, there is that option as well.

Also, the program must be highly interactive and responsive. Changes to the composition must immediately affect the music that the program produces so that students receive immediate

feedback. As previously mentioned, these goals are conducive to promoting a state of flow for students. Similarly, students should be able to experience the music visually as well. Beyond just visualizing music, the program provides a means for animating the music.

Finally, to achieve this multimodal interactive approach to creating compositions, there must be multiple means of interacting with the composition. The current prototype for the program presents two possible methods: traditional music notation and a hierarchal sequencer view. These modes are quite different but certainly not exhaustive. For that reason, the program should allow for modularity in the sense that different user interfaces cannot only interact with the music being produced, but also utilize the same metadata created in other user interface views. In other words, if there was a user interface that was developed so that music was visualized in tablature, that user interface could be inserted into the program and interact with the music with little to no complications.

Therefore, due to the nature of these requirements, the components to be included as a part of this program include an audio library that will manage audio manipulation and particularly reading files, combining them, and sending them to audio output. A graphics library will be necessary to produce a user interface and visualize the music being manipulated. Since the goal is to allow freedom of creativity, the program should allow for the importing of audio and graphics so that children can bring in individualized sources of media. This program should visualize music similar to a sequencer like GarageBand and should also allow for music to be visualized by manipulating traditional music notation similar to a product like Finale or Sibelius.

There are two chief technical concerns when choosing programming languages and frameworks for this project. This project has to be versatile due to the fact that its goal is to be used on multiple device types. This project will also be resource intensive. Audio processing and

visually interactive applications use a lot of the computer's memory and processing resources as there are many calculations that need to occur very quickly for these programs.

To meet these needs, there were several choices. However, many have their drawbacks. Ultimately it was decided that the Java programming language along with a gaming library such as libGDX (http://libgdx.badlogicgames.com/) or playN (https://github.com/playn/playn) would work well. Java as a programming language performs well compared to some other languages like JavaScript, the language of the web, but allows for code much simpler and usually more portable than some other programming languages ("X64"). A gaming library provides many fundamental components necessary for this project such as access to audio, visual and user input resources. A gaming library must be high-performing due to the computing demand for games.

Fundamentally, this program needs to keep track of when sounds need to be played and then play them at the right time. These sounds can be pre-recorded sounds like a recording of people singing or a recording of a bus horn. These sounds can also be computer generated. For instance, the computer could generate a second-long clip of the pitch of a C4. Ultimately, sounds have a starting time, and when that starting time is reached, the sound needs to be played. One approach to this problem would be to take the audio information from the sounds being played at any given time, combine the audio information, and then send it to the computer's speakers.

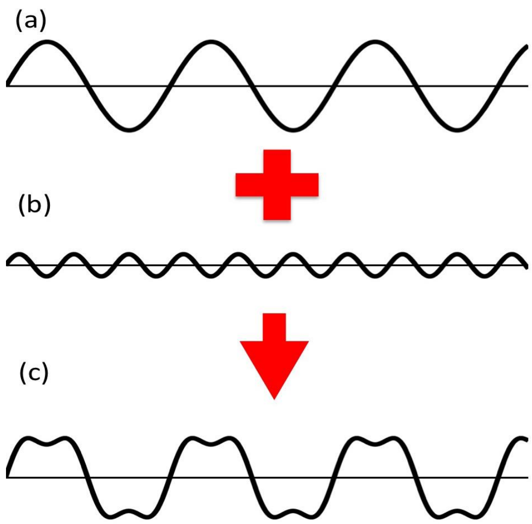

Fig. 1. When a sound (a) is combined with another sound (b), it produces the combination of the two (c).

This is probably the optimal solution as it allows for the most control, would probably be the best performing, and would allow for audio effects on sounds as well.

The traditional way that audio data is encapsulated digitally is using Pulse-Code Modulation referred to with the acronym PCM ("PCM"). As an example, Audio CDs are encoded using PCM data ("PCM"). In PCM, the audio is time-sliced into samples ("PCM"). So a sample rate of 44100 HZ (the typical sample rate for an Audio CD) refers 44,100 samples per second ("PCM"). Then the amplitude for each sample of the audio is recorded. A stereo recording further complicates matters as there is the amplitude for the left channel and the amplitude for the right channel ("PCM").

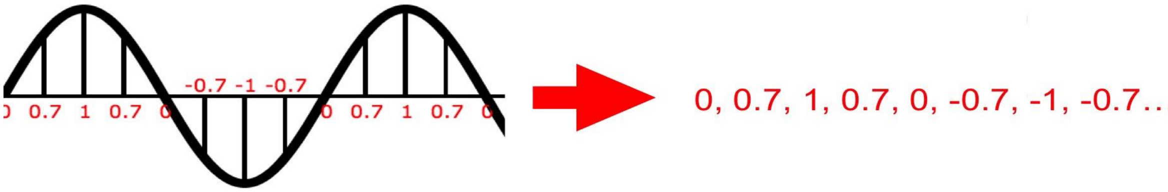

Fig. 2. A sound wave's amplitudes are sampled at a consistent period when converting to digital audio.

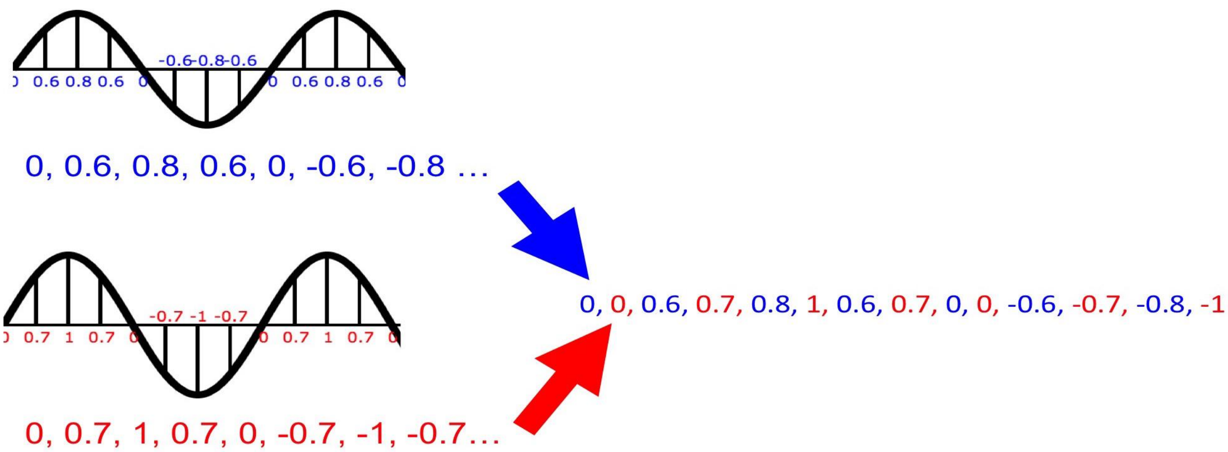

Fig. 3. For stereo samples, amplitudes from the left channel are intermingled with amplitudes from the right channel when converting to digital.

During playback in the application, the program considers about a half second's worth of audio at a time. The audio data from the sound files is converted into a series of amplitudes. Then the amplitudes for the sound files to be played at that time are added together. The sum of amplitudes is then converted back into binary information that the speaker driver can understand.

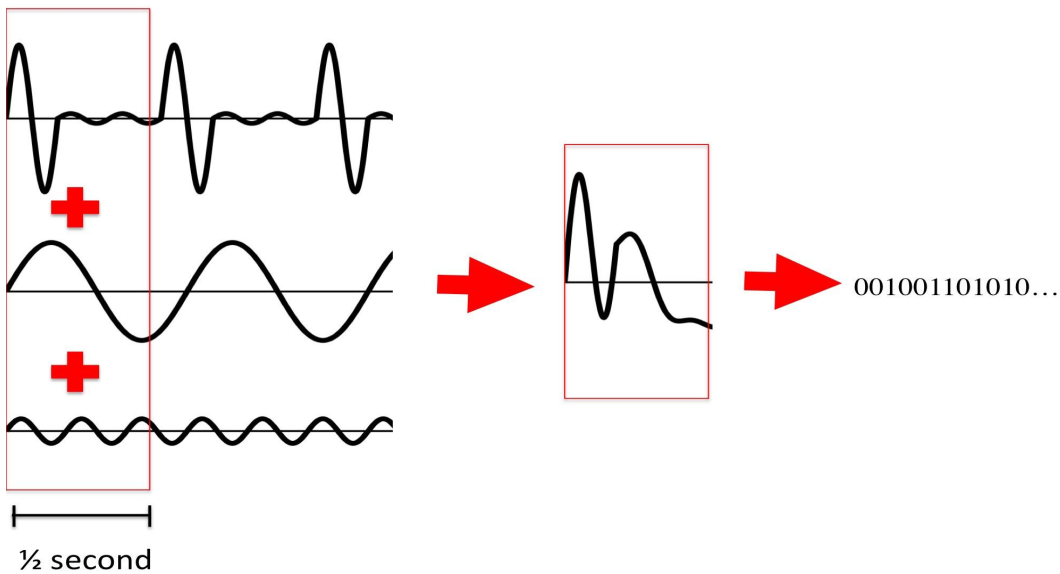

Fig. 4. During playback, a half second's worth of audio is combined and converted to a digital signal for playback.

There is the potential before the audio is converted back to binary, to apply effects to the audio as well. An audio effect such as an echo can easily be created by mimicking that waveform at a smaller amplitude with a given delay from the original.

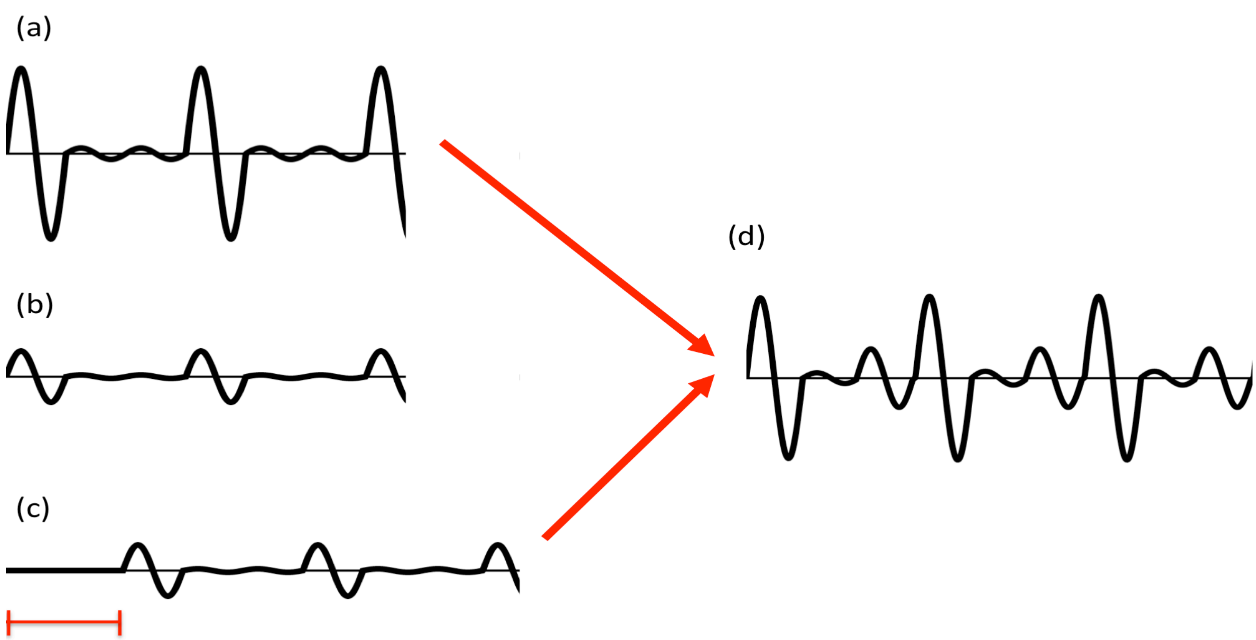

Fig. 5. To produce an echo effect for audio, the original audio (a) is diminished in amplitude (b), offset by the delay (c), and combined with the original audio (d).

There is another method by which these sounds can be positioned and played properly. Instead of manipulating the audio data manually, a timer can be set for individual sounds. When the timer goes off, the corresponding sounds are played.

There are positives and negatives to both approaches. When the audio data is manipulated manually, there is the potential for fine-grained control. Audio effects can be applied directly to the audio data. Also, the accuracy and efficiency is significantly better than the alternatives. With the timer approach for the audio, there are fewer options for applying audio effects, and the precision is not guaranteed to be as accurate. However, it is a lot easier to proceed with this implementation and in certain circumstances, it is the only path. For a web application, it is not typically possible to manipulate the audio data manually. So, for a web application, the timer approach is the only true option.

In both approaches, the audio data is managed as part of an audio timeline. The audio timeline keeps track of the start time of each piece of audio. This timeline is segmented typically into half-second amounts. During playback, all the sounds at the particular piece are considered. The playback mechanism accounts for the offset of the sound within the particular piece of audio (e.g. a sound might start right at the beginning of the segment or mid-way into the segment), then the audio is combined and sent to the speakers. While the audio is playing on the speakers, the next chunk of audio is being calculated.

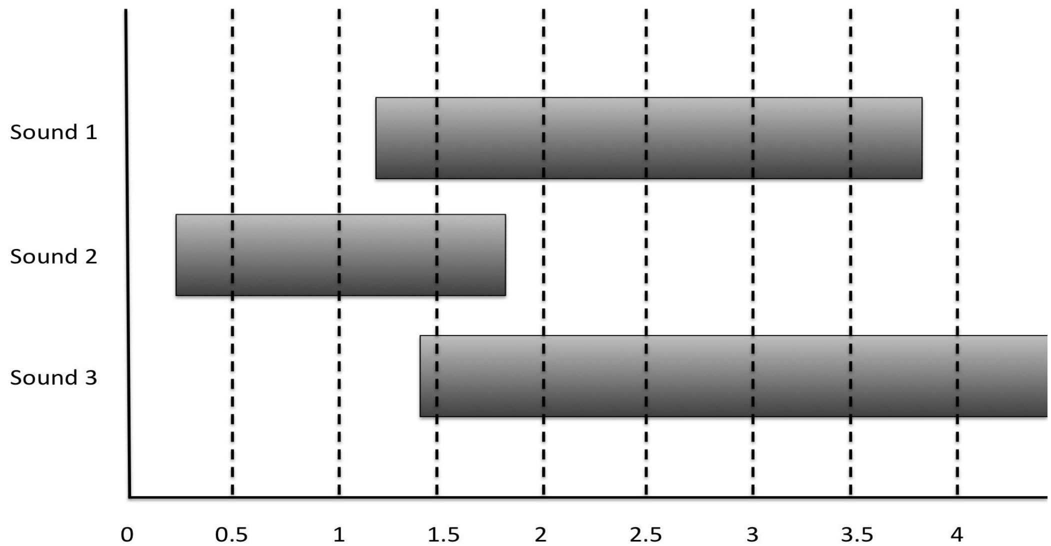

Fig. 6. The audio timeline is segmented into half-second increments. During playback, a half-second's worth of audio is considered at a time.

In computing terms, these segments are called a data buffer. When a video is being buffered over the internet, it is gathering a chunk of video data on the local computer so that that piece of video can play while the next video buffer is determined. To calculate the audio output for an entire project would require a lot of time and would require a lot of resources on the computer. It also would not allow the audio to be adaptable to real-time changes. For instance, if something were changed in the project, those changes would not appear until the audio was recalculated. If the audio for the project were calculated in its entirety, those changes would never appear. Whereas if a small buffer were calculated at a time, those changes could appear once the next buffer is calculated.

The audio timeline helps organize the sound information to assist in playback. This audio timeline keep track of audio and its respective start time for the computer. However, a user cannot make much sense out of a sound and its start time without some context. Ultimately, this audio timeline needs to be adapted so that a user can make meaning out of the composition and can interact with the audio timeline.

This is where metadata comes into play. Sounds have information that is attached to them to illuminate important information. This information could include the pitch of the note, what instrument made the note, and other similar information. The important aspect of metadata is that this data can be utilized by various views of the same music. For instance, in a music notation view of the music, the pitch of the sound is necessary to determine where it falls on the staff. In the sequencer view of the music, what instrument plays the note could become extremely important.

Metadata also contains information that is not directly pertinent to sounds. Music notation has several aspects of this. Music notation has elements like time signatures, key signatures, and clefs. These elements are not pertinent to any particular note; however, they provide context for how the music is interpreted. Similarly, there are some subtle nuances that pertain to music that assist in interpretation, but have no effect on the sound. For instance, a quarter note is equivalent to an eighth note tied to another eighth note. Both instances have the same duration of sound, but there are certain contexts where a quarter note would be preferable for readability's sake.

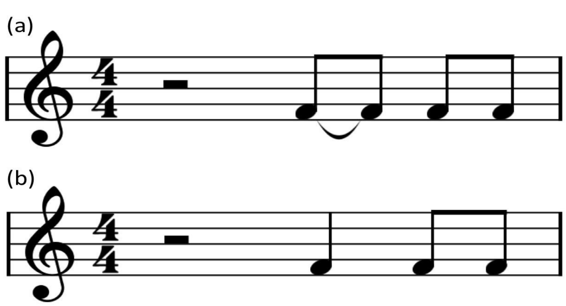

Fig. 7. The notes in the first measure (a) make less sense idiomatically than the notes in the second measure (b).

Finally, as listeners, we make abstractions of time that are not necessary for a computer. The most logical way to deal with time for a computer is to use standard metrics like seconds (and often to the precision of milliseconds). Beats, measures, and fractional note values (e.g.

quarter note, half note, whole note) are human concepts of time. A beat is really just another way of thinking about time and can be directly converted to seconds based on the beats per minute (i.e. length in seconds = beats * 60 / bpm). Likewise, note values (e.g. quarter note, half note, whole note) are an abstraction of the beat based on the time signature. The length of a half note in beats can be determined based on what note gets the beat in the current time signature. These abstractions are dealt with by keeping track of bpm changes and time signature changes throughout the course of a piece. For example, when a conversion is needed between seconds and the fractional value of note, the program looks up the current bpm marking as well as the current time signature. All of these changes are stored as metadata. With this metadata, the original timeline keeping track of sounds' start times in seconds can be converted to a timeline keeping track of notes and their respective start time in beats for a music notation view of the music.

There is also a need to filter data in these timelines. A stave in music notation is only concerned with notes played by that particular instrument. Similarly, there are instances in the sequencer where only some of the sounds should be shown. By filtering the original timeline, a new view of the timeline can be created with only the pertinent information in it.

The goal in the design of this sequencer was to approach form in a different way. Form, on a large scale, consists of things like ABA, rondo, through-composed, etc. Traditionally, sequencers have allowed for sectioning the music. For example if someone were to create an example of ABA form in a sequencer like GarageBand, the first and last sections would be the A section, and the middle section would be the B section.

However, forms can be nested. For instance, an A section can contain a musical period, which can contain a phrase, which can in turn contain a question and an answer. Similarly, the A

section of a rhythm changes standard can feature the rhythm section riff, the horn backups, and a guitar solo.

We typically think of forms in these groupings when writing and listening to music and this is the impetus behind this version of a sequencer. In this sequencer, someone can create a block representing the A section. That A section can contain blocks representing the phrases in that A section. Those phrases in turn, can contain a block representing the call and a block representing the response. This ultimately allows the composer to make groupings and connections in the music that are more pertinent to the composer and potentially the listener as well.

The other substantial change in this sequencer is that elements of music can be visualized in different ways. Each block of music has an image representing that sound. The A section of a piece could quite literally be represented with a picture of an "A" just as easily as it could be represented with a picture of a purple square. Also, each block has an animation that can be associated with it. Therefore, a block representing a phrase could bounce to the beat as it is being played. This moves towards providing a better multimodal learning experience for the students as well as being more engaging.

Music notation is a difficult thing. It is difficult to comprehend and it is much more difficult to write. Consider the student who says, "what does it mean when the line goes down," referring to the stem of a quarter note facing downward instead of upward. As a trained musician, it might be easy to brush off the question with a simple answer saying that it has to do with where the note is on the music staff. However, a note with a downward facing stem is visually different than the note where the stem faces upward. This visual difference might suggest it is a different entity; however, that is not the case. Conversely, a half note and a dotted

half note look exactly the same except for a dot, and yet they have a different value for the time they consume.

These are just a couple of the many intricacies involved with music notation. There are a handful of other examples, where even trained musicians might be scratching their heads for the answer. For instance, if there were eighth notes with the pitches of C4, D4, and E4, note heads will have to alternate on which side of the stem they are. To determine which side each note head is on is based on what the current clef is and whether or not the eighth note is tied, because ultimately, this is a determination based on whether the stem goes up or goes down. This might sound like music notation minutiae, but these rules are necessary for precision in notation and often times, clarity in reading. However, these rules add to the complexity in reading music and to writing music. To explain to a computer how even simple notes should be rendered becomes a somewhat complicated task.

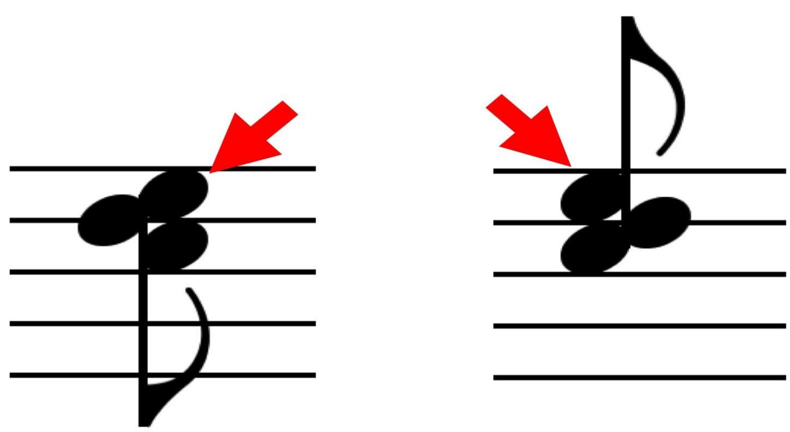

Fig. 8. Note head displacement is effected by the stem direction.

There are a few music notation software libraries that exist that partially meet the goals of this project, but none that do so entirely. The Guido Engine Library (http://guidolib.sourceforge.net/) as well as Belle, Bonne, Sage (http://bellebonnesage.sourceforge.net) were potentially good options, but they did not interact in

a way that would allow them to be used as broadly as the scope of this project. Namely, it might be difficult to integrate with other existing code and would be difficult to integrate particularly for a web version of the software. VexFlow (http://www.vexflow.com/) was a potentially successful option, but the design of the software library did not allow it to easily break components into pieces. For instance, it would be somewhat difficult to render a quarter note without rendering it on a music staff using VexFlow. In the context of some goals for this notation library, modularity was key. A quarter note should be able to be rendered without the context of a staff. VexFlow did not lend itself easily for user manipulation. It was designed as music engraving software and not for manipulation similar to Finale or Sibelius. While not an immediate goal, a secondary goal for this music notation library is extensibility. For instance, it would be nice to allow for boomwhacker notation where noteheads would be colored the same as the boomwhacker color for the same pitch. This could note easily be done using something like VexFlow.

So, since these libraries were not quite adequate for the scope of this project, a new music notation software library has been created to meet those needs. The main idea behind the implementation of this music notation library was to treat music notation like a hierarchical layout. For example, webpages work on this principle. In the below example, there is a division. Inside that division is a table, and within the table is some text.

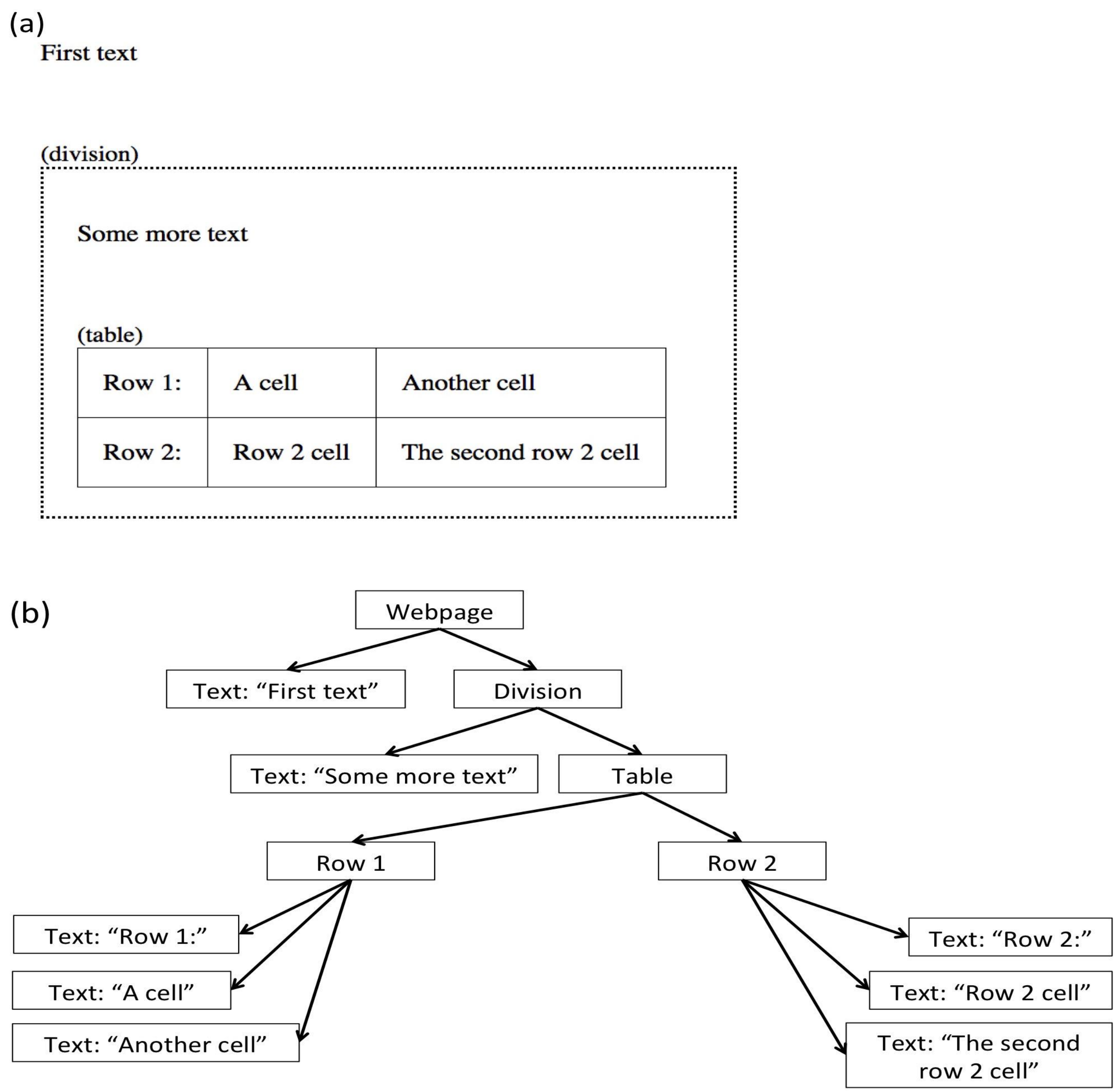

Fig. 9. The structure for a simple webpage (a) represented hierarchically (b).

A score on the outset has attributes similar to this hierarchical layout. A score takes on the size of its systems. Systems take on size of all measures in that system. A measure takes on the size of all its notes, and finally a note takes on the size of all its subcomponents (e.g. dots, note heads, accidentals, articulations).

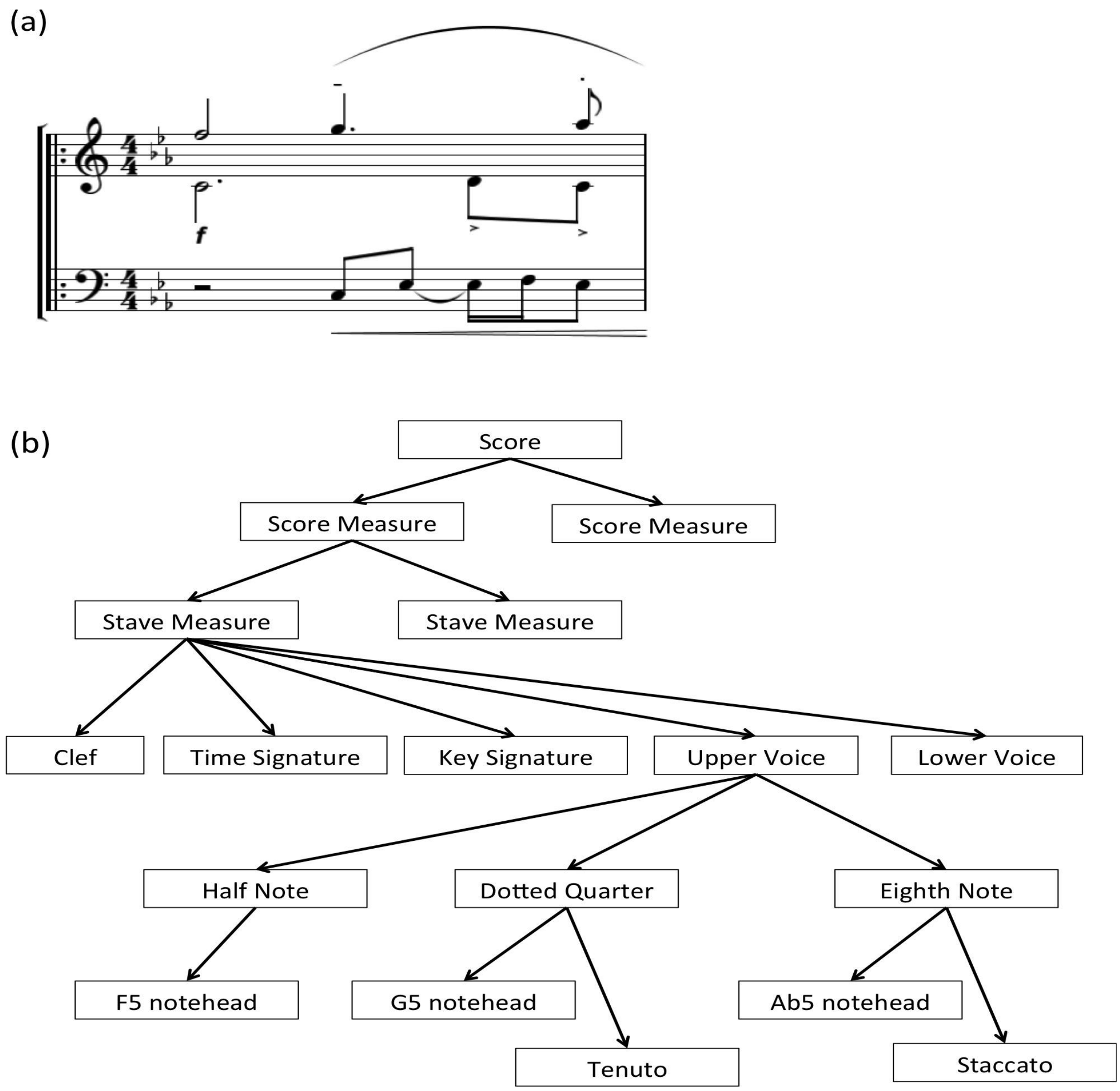

Fig. 10. The structure for a score (a) represented hierarchically (b).

However, there are several aspects of this layout that add additional layers of complexity. While music notation is hierarchical in a sense, it is also very much interrelated. For instance, while notes belong to a measure, notes receive their x position so that notes align vertically based on their time.

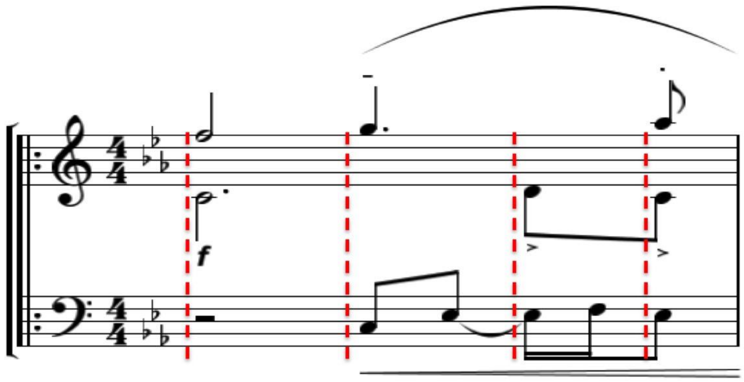

Fig. 11. Items that occur on the same beat should be aligned vertically in a score.

Another example of this is accidentals. Accidentals are laid out to the left side of the note head. Typically, given enough spacing, these accidentals should be right in a line. However, the spacing changes when accidentals are located too close to each other.

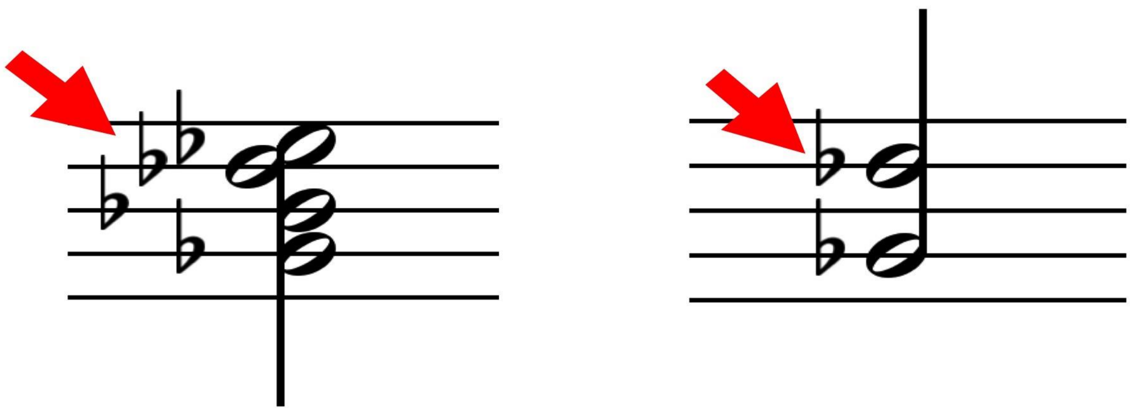

Fig. 12. Accidentals for a note are displaced when note head density would cause accidentals to overlap.

There are many more examples of these subtle complexities in music notation that cause an additional layer of difficulty in rendering music.

Chapter 6: Findings

During the survey, some technical difficulties were found. According to one person surveyed, “when I switched to the notes screen, it froze a couple of times.” There were a handful of items in the musical notation portion of the program that need some refinement. Specifically, when the program first parses note values, it occasionally has difficulty determining the proper rhythmic value for notes based on their duration.

Surveyed individuals also mentioned some features that either needed more refinement or further development. One person stated, “it was also a little cumbersome drawing a shape and then moving it to where I want it; being able to choose a destination before drawing a shape would be helpful.” In the sequencer, when a block of sound was added, it was initially placed at the very beginning of the song. In addition, the screen viewport does not follow the playback position of the sequencer. Also, while most controls are mostly modeled after commonly used components, some controls defy user expectations. As an example, in order to add a sound to the sequencer, the user uses a menu with potential sound choices. The user can click on a sound choice, and then click the okay button. However, one teacher suggested that it would be nice to be able to double click to add the sound instead. Also, someone suggested that the sequencer could have scroll bars to indicate that the sequencer area can be scrolled and provide a more familiar user experience.

There are a handful of other items in this application where the user needs to be provided with more useful visual or audio feedback. For instance, before choosing a sound to add to the sequencer view, the user should be able to sample and test the sound. The melody creator provides a unique way to visualize and create a melody. However, once a melody is created, there is no means to edit it with the melody creator. One user suggested allowing for the editing

of melodies within the melody creator after it is created. Also, one teacher suggested that there should be a means to make notation more accessible for younger students who are first learning how to read music notation. The application could adjust the octave of notes accordingly so that notes appear on the staff for the sake of readability.

Beyond some usability issues, there were some features that needed further expansion. Someone stated, “a guide saying what shape produced which sound of melody would be helpful. I like being able to draw shapes that correspond to sounds/ melodies, and think kids would certainly benefit from it, but I couldn't get it to make the specific shapes I wanted.” When the sequencer adds a block of sound, it automatically chooses a random image, color, and animation. Choosing the color, shape, picture, or animation for any sound in the sequencer was considered as a feature for implementation, but this feature was not high priority for the initial release of this software.

Similarly, the melody creator only allows for creation of a melody in C major pentatonic. However, this severely limits the potential uses of this application. So, while there was no feature in the initial release to change the potential scale used in the melody creator, the option to change the scale could dramatically increase the potential uses of this software. Also, the melody creator determines the melody based on the closest eighth note. However, the melody creator could use any predetermined rhythm. The melody creator could also provide some visual indication as to which height corresponds to which note. Currently, there is no way to tell if a note created in the melody creator will become a G or an A. This feature might not be as important to very young students where the actual notes probably do not matter as much, but this feature might be beneficial to students who have an understanding of what these different notes might mean.

Finally, the music notation portion of the application could be more extensible if it allowed for multiple staves and clefs. One teacher suggested that if the application would allow for alto clef and bass clef, students who play in her orchestra could create songs and melodies that they could play on their instruments. Similarly, if the program allows for instrument transposition, students in band could create songs and melodies that they could play as a class despite the different instrument transpositions.

Beyond these fixes and improvements, teachers saw potential uses of this software within the classroom. Since the melody creator relates high and low pitches to higher or lower places on the screen, this could be used with younger students to convey the idea of high and low pitch. One teacher suggested that this program could potentially be used to teach different instrument families. Since the sequencer uses different shapes to represent different sounds, the sequencer could very similarly represent different woodwind recordings with pictures of corresponding instruments. In fact, finding ways to visualize sound and music was one of the main goals for the creation of this project. One alternative path for this software might be to move this closer to a music equivalent of interactive whiteboard software similar to Smart Notebook (https://education.smarttech.com/en/products/notebook/download) or Promethean's ActivInspire software (http://www.prometheanworld.com/us/english/education/products/classroom-software/activinspire/).

Towards this application's goal, teachers noted ways it could be utilized in music composition. One teacher remarked that students could quite literally see how pieces of a song could fit together. Also, the application could help reinforce musical rules. For instance, the melody creator enforces that notes are within a certain scale. The sequencer not only enforces but also shows the size and positions of sounds. So, if a sound or melody is eight beats, it will

take up eight beats worth of space in the sequencer and will show students how much space is actually used. Another suggestion from a teacher was that students or groups of students could potentially have ownership over one region of the song in the sequencer as a region of the screen relates to a portion of time in the song. Finally, if the melody is easily accessible and easily readable, songs and melodies that are created in the application could be played by students on instruments. Students could play songs and melodies on Orff instruments, recorders, boomwhackers, or other classroom instruments. With a little finessing of the application, the application could also be used to create compositions that students who play an instrument in band or orchestra could play in class or practice at home. The application could provide a certain amount of scaffolding in the process as the song could be played by the application itself.

Chapter 7: Conclusion

Throughout this process there were some pitfalls and some unforeseen complexities. Music notation presented a particular complication during the process. Originally, it looked as though it might be possible to utilize a previously created music notation library. There are several pieces of software that could potentially be utilized, but most of them fell short for the requirements of this project. Also, music notation, as previously mentioned, is a deceptively complicated task. In fact, “Behind Bars: The Definitive Guide to Music Notation,” written by Elaine Gould was used extensively as a resource for some of the finer points of music notation.

Beyond music notation, there were some other unforeseen technical concerns. The gaming library presented the wonderful ability to allow the same base of code to be utilized on various platforms. This was particularly helpful for development as the program could be tested from a desktop environment, but was ultimately deployed to a webpage for distribution. However, since this gaming framework needs to target multiple systems, this framework supports only the abilities that are common to all systems. This presents a particular complication when dealing with audio. Since this program requires a great deal of precision and flexibility when it comes to audio, the gaming framework needed to be supplemented heavily in the area of audio processing.

There were a few aspects of the application that fell short of expectations. The music notation aspect of the program could be improved to remove bugs and improve the user experience as well. Some of the components such as menus and buttons could be refined and made more user friendly. Also, some of the features, as previously mentioned, could be improved and refined.

Despite these shortfalls, many features of the program function well. The melody creator was fairly successful. The sequencer portion of the program, as well as the music notation portion, is functional and usable, albeit somewhat buggy. This software provides a foundation that could be expanded and developed in many different facets. The aspects that were somewhat cumbersome could be refined and improved and functionality could be expanded making this a useful piece of software in the music classroom. Also, this software has many building blocks that could be potentially used in different ways in the future. So, while there are still aspects of the program that need to be developed, there is some tremendous potential for both the application as a whole as well as the individual components to assist younger students in their creative aspirations.

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