Tackling Engagement in Computing with Computational Music Remiking

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ABSTRACT

In this paper, we describe EarSketch, an integrated curriculum, software toolset, and social media website, grounded in constructionist principles, that targets introductory high school computing education. We hypothesize that the use of collaborative computational music composition and remixing may avoid some of the engagement and culture-specific issues that other approaches, both in music and other media, have had. We discuss the design of EarSketch, its use in a pilot summer camp, and the evaluation results from that pilot.

Categories and Subject Descriptors

K.3.2 [Computers and Education]: Computer and Information Science Education – computer science education.

General Terms

Design.

Keywords

Music, education, computing principles, remixing, collaboration.

1. INTRODUCTION

Computing education in the United States currently struggles to engage students and motivate their further studies in the discipline [6]. This challenge is more pronounced with under-represented groups and particularly with African-Americans [4,29]. Previous research has attempted to increase minority participation in computing education by making it more relevant and engaging through culturally-specific technology [3,7,29]. Other approaches to engagement have turned to more general contextual motivators, such as the computational creation and control of movies, music, textiles, animations, robots, and especially computer games as an “in” for motivating students to study computing [5,8,11,12,16,22].

EarSketch, our approach to engaging students in computing principles through collaborative computational music composition and remixing, consists of an integrated curriculum, software toolset, and social media website. The EarSketch curriculum targets introductory high school computing education. The software toolset enables students to create music by manipulating loops, composing beats, and applying effects with Python code. The social media website invites students to upload their music and source code, view other students’ work, and create derivative musical remixes from other students’ code. EarSketch is built on top of Reaper, an intuitive digital audio workstation (DAW) program comparable to those used in professional recording studios. It is extremely practical for educational settings due to its low cost, cross-platform compatibility, and low processor and memory utilization.

EarSketch is designed to enable student creativity, to enhance collaboration, and to leverage cultural relevance. This focus has created unique advantages for our approach to computing education. First, EarSketch leverages musical remixing as it relates to popular musical forms, such as hip hop\(^1\), in an attempt to connect to students in a culturally relevant fashion that spans gender, ethnicity, and socioeconomic status. It does so by explicitly connecting the learning environment to popular music production software, by drawing from industry practice in the features it supports, and by visualizing computational output within standard studio paradigms. It also focuses on the level of beats, loops, and effects more than individual notes, enabling students with no background in music theory or composition to begin creating personally relevant music immediately, with a focus on higher-level musical concepts such as formal organization, texture, and mixing. Second, student use of the social media site allows a tight coupling between code sharing and the musical practice of remixing. Students can grab code snippets from other projects and directly inject them into their own work, modifying them to fit their idiosyncratic musical ideas. Third, unlike more graphically-oriented environments such as Scratch, EarSketch builds on professional development techniques using an industry-relevant, text-based programming language (Python), giving them concrete skills directly applicable to further study.

2. EARSKETCH

2.1 Technical Design

EarSketch integrates three components into the Reaper software: an application programming interface (API) for controlling Reaper, a sound library of pre-composed audio loops; and utility scripts to seamlessly integrate with other EarSketch components.

The EarSketch API leverages ReaScript, Reaper’s own Python API that provides low-level programmatic access to Reaper. We

\(^1\) Hip hop music has widely embraced the remixing of other artists’ musical works as a post-modern music composition practice since the 1970’s [25].
have developed our own higher-level Python API for pedagogical use that wraps the ReaScript API. It focuses on typical composition and remixing tasks, such as placing audio files on the timeline, applying effects, and sequencing rhythmic beats.

We have also used ReaScript to customize the functionality of Reaper’s user interface, hiding extraneous GUI items and adding menu commands to run and edit Python scripts, upload projects to the social media site, and access EarSketch curricular materials.

Since EarSketch relies heavily on the manipulation of pre-composed audio loops, it requires an extensive audio loop library. For this workshop, we licensed a commercial loop library that includes a variety of genres, so that students can create pieces that reflect their own interests and tastes: hip hop, soul, R&B, techno, house, drum n bass, and Latin/world.

2.2 Curriculum Design
The curriculum incorporates basic computing concepts grounded in “thick authenticity”; which focuses on the interrelated authentic learning practices of: having personally meaningful learning experiences; learning that relates to the world outside of the learning context; learning that encourages thinking within a particular discipline, like music composition; and allowing for assessment that reflects the learning process. The curriculum has been based on the CS Principles topics [31] within the context of loop-based composition (see Section 2.2.1). Students learn how to create music with digital audio workstation (DAW) software, to write code to programmatically generate music in the DAW, and to create both music and code collaboratively.

2.2.1 Overall Design
The EarSketch curriculum is currently designed for use in a summer workshop setting (see Section 3) and will soon be adapted for use in an academic high school classroom. The curriculum does not expect students to play a musical instrument or read music notation. It also assumes that students have no prior experience in using DAW software or in programming. Its design emphasizes hands-on, collaborative experiences.

The curriculum also emphasizes some of the unique benefits of approaching music from a computational perspective. In particular, it demonstrates to students how to rapidly experiment with many possible variations on a musical idea by iteratively modifying algorithmic parameters, executing each version of code, and using their musical ears to decide which option(s) are best [8]. (For example, they may explore how many times a loop should be repeated before a new one is introduced.) The curriculum also focuses on the idea of a composer as a “pilot” who uses computation to negotiate low-level details so as to focus more on higher-level musical structures and on the ways in which a computational interface transforms musical thinking [30].

We formulated learning objectives based on the current CS-Principles learning objectives [31], adopting the relevant objectives to our specific domain. For example (italics indicate EarSketch-specific language): Learning Objective 5: (CSP-14) The student can analyze the considerations involved in the computational manipulation of musical sounds and ideas. These learning objectives were directly used in designing our assessment instruments (see Section 4.1).

2.2.2 Digital Audio Workstation (DAW)
The first topic covered in the curriculum is the Reaper DAW. The DAW is the timeline-based software program that lets users place sound clips on tracks, as well as add and manipulate effects.

Before coding, students first learn how to create music using Reaper’s standard graphical interface. This familiarizes them with music industry software paradigms, helps them build a mental model of the DAW as a foundation for further programming abstractions, provides clear connections between API functions and standard DAW functionality (e.g. insertMedia() corresponds to dragging an audio clip onto the timeline), and demonstrates the unique advantages and time savings programming can offer in executing complex tasks.

2.2.3 Programming
Programming concepts in the EarSketch curriculum are introduced in hand with DAW capabilities and musical constructs. The current workshop curriculum covers basic Python syntax (e.g. comments, imports); the use and declaration of variables, functions, and parameters; iteration with for loops, index variables, and skip counting; strings; simple math and random functions; and list data structures.

Figure 1. Example of Reaper’s graphical interface
function to more easily create and control effects and parameter changes programatically.

Collaboration and sharing are incorporated into the curriculum at all levels. After each lesson, students have time to work on their own projects, frequently collaboratively. We use “round robin” and “pair” style coding, where students work for five minutes on a project, then continually shift one seat over in the classroom to a new project or alternate back and forth with a single collaborator on the same project. All of this work is placed onto the social media web site, allowing students to view and download other students’ projects. By appropriating musical ideas and programming techniques from uploaded work, collaborative practices emerge even without direct pairing or contact.

2.3 Social Media Site
Our social media web site facilitates informal sharing and borrowing of code among students. Following the paradigm established by online music remixing communities such as ccMixter [1] and computing education communities such as Scratch [18], the site enables students to browse projects created by their peers, listen to the audio and view the code inside the browser, download the project, add comments and tags, and see how code has been reused and transformed by others. To facilitate seamless integration, we created a menu command within Reaper that automatically uploads a user’s relevant source code and audio files for a project to his or her social media site account.

3. SUMMER WORKSHOP
During summer of 2012, we conducted the first EarSketch workshop to pilot the curriculum, software, and social media site. The workshop consisted of 5 days of instruction, approximately 5 hours per day, with each day being divided into 60-minute segments. These segments were designed to provide a comfortable amount of time for instruction and demonstration with longer periods of time for individual student practice and application, followed by sharing and reflection. Students had specific assigned exercises, more open-ended work time, and round robin, pair programming, and kinesthetic activities. Besides the instructor lessons, they also had access to an EarSketch curriculum manual and reference documentation. Ultimately, the students worked to create a final project to present and share with family members during an “open house” which took place on the final afternoon of the workshop.

Many of the recruited students enrolled in the workshop due to an interest in music. These students’ intrinsic motivation for creating music was used as a foundation for an interest in programming. Students were encouraged to bring an instrument or to utilize the in-room keyboard along with a recording system to test musical ideas. Several students were able to record their own music and incorporate it into their personal projects. In-class “jam” sessions where the students would improvise and play music occurred a number of times throughout the course. Students also frequently brought in musical ideas from popular commercial recordings that became seeds for their projects.

4. EVALUATION
The students that participated in the EarSketch workshop were from a variety of Metro Atlanta and Atlanta schools. Rising 9th and 10th grade students made up 70% of the group while the remaining 30% was made up of 11th and 12th grade students. The ethnic demographic of the group was relatively diverse with 18% of the students being Asian-American, 24% being African-American, 53% European-American, and 6% of two or more ethnicities. The class was comprised of 75% male and 25% female students. These workshop participants were recruited through the Georgia Tech Institute for Computing Education (ICE). 82% of the students had never been previously involved in a computer science related workshop.

4.1 Methods
Program participants were measured at three time points over their 5-day EarSketch experience: a 10-item pre content knowledge assessment on day one, an engagement survey at the end of day four, and the same content knowledge assessment on day five that the students saw on day one. The content knowledge assessment is designed to measure basic knowledge related to programming a digital audio workstation environment and adheres to a set of standards developed by the EarSketch curriculum team. We focused on novice-level concepts in teaching materials and assessment, using Bloom’s Taxonomy [15] as a guide for focusing on 1st (knowledge) and 2nd level (comprehension) learning. Before administering the assessment, the team rated the difficulty of each item in relation to this taxonomy as: easy, moderate, and difficult. Figure 2 shows an example of a moderate difficulty question.

Figure 2. Example of a moderate content knowledge assessment question

<table>
<thead>
<tr>
<th>Which code example puts the beat “0+++0+++0+0+0+++” on measures 5, 6, 7, 8?</th>
</tr>
</thead>
</table>
| 1. music = HIP_HOP_DRUMS4_2M  
| for measure in range(5, 9):
| makeBeat(music, 1, measure, “0+++0+++0+0+0+++”)
| 3. music = HIP_HOP_DRUMS4_2M  
| for measure in range(1, 5):
| measure = measure * 2
| makeBeat(music, 1, measure, “0+++0+++0+0+0+++”)
| 5. music = HIP_HOP_DRUMS4_2M  
| for measure in range(4):
| makeBeat(music, 1, measure, “0+++0+++0+0+0+++”)
| 6. I don’t know

On day four, participants were asked to complete a survey measuring seven engagement constructs [27]. The engagement instrument is comprised of five scales from Williams et al. [28]:

- computing confidence (e.g. “I am sure I can do advanced work in computing”),
- computing enjoyment (e.g. “I feel comfortable working with a computer”),
- perceived usefulness of computing (e.g. “I will be able to get a good job if I learn how to use a computer”),
- motivation to succeed in computing (e.g. “I like solving computing problems”), and
- computing identity and belongingness (e.g. “I feel like I ‘belong’ in computer science”).

The instrument also draws on a scale [14] designed to measure the extent to which participants see computing as a creative outlet (e.g. “I am able to be very expressive and creative while doing computing”). Finally, the instrument measures students’ intention to persist in computing as a field of university study and a career
(e.g. “Someday, I would like to have a career in computing”). The student engagement survey was administered retrospectively, such that students’ answered how they felt before the week-long EarSketch camp and at the end. This instrument was administered at the end of the fourth (of five) day of camp. The analysis consisted of a paired samples t-test whereby statistically significant changes from pre to post were assessed.

4.2 Results
Overall, the results suggest that students’ attitudes positively and statistically significantly increased across 3 constructs at p<.01: Computing Confidence, Motivation to Succeed in Computing, and Creativity. This suggests that the workshop is effective at enhancing students’ perceptions that they can tackle advanced computing work and get good grades in computing (Computing Confidence). Likewise, the workshop increases students’ motivations to persevere on complex computing problems (Motivation to Succeed in Computing). Originality and expressivity are also enhanced as a result (Creativity). Students’ enjoyment and perceptions of the importance and usefulness of computers were, comparatively, high both before and after the workshop; this suggests that the workshop maintained students’ positive perceptions of computing. Students indicate that they are statistically significantly more likely to see themselves in a computing field in the future as a result of the workshop.

Table 1. Change from before to after along the seven engagement constructs

<table>
<thead>
<tr>
<th>CONSTRUCTS</th>
<th>Before</th>
<th>Mean</th>
<th>Now</th>
<th>Paired Samples t-test</th>
<th>SD</th>
<th>D</th>
<th>N</th>
<th>A</th>
<th>SA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computing Confidence</td>
<td>16</td>
<td>3.20</td>
<td>17</td>
<td>4.11</td>
<td>0.008**</td>
<td>14%</td>
<td>18%</td>
<td>24%</td>
<td>22%</td>
</tr>
<tr>
<td>Computing Enjoyment</td>
<td>17</td>
<td>4.31</td>
<td>17</td>
<td>4.34</td>
<td>0.838</td>
<td>2%</td>
<td>5%</td>
<td>11%</td>
<td>25%</td>
</tr>
<tr>
<td>Perceived Usefulness of Computing</td>
<td>17</td>
<td>4.39</td>
<td>17</td>
<td>4.11</td>
<td>0.945</td>
<td>3%</td>
<td>1%</td>
<td>11%</td>
<td>25%</td>
</tr>
<tr>
<td>Motivation to Succeed in Computing</td>
<td>17</td>
<td>3.57</td>
<td>17</td>
<td>4.03</td>
<td>0.000**</td>
<td>1%</td>
<td>7%</td>
<td>17%</td>
<td>39%</td>
</tr>
<tr>
<td>Computing Identity &amp; Belongingness</td>
<td>17</td>
<td>3.59</td>
<td>17</td>
<td>3.76</td>
<td>0.277</td>
<td>2%</td>
<td>20%</td>
<td>27%</td>
<td>20%</td>
</tr>
<tr>
<td>Intention to Persist</td>
<td>17</td>
<td>3.58</td>
<td>17</td>
<td>3.70</td>
<td>0.245</td>
<td>5%</td>
<td>12%</td>
<td>33%</td>
<td>22%</td>
</tr>
<tr>
<td>Creativity</td>
<td>16</td>
<td>3.46</td>
<td>17</td>
<td>4.20</td>
<td>0.006**</td>
<td>9%</td>
<td>5%</td>
<td>38%</td>
<td>28%</td>
</tr>
</tbody>
</table>

**p<.01; *p<.05; negatively worded items were reverse coded prior to mean computation of the constructs. Only students with matched before and now scores were assessed for statistical significance. Note: We employed a 5pt. scale with the following response categories: Strongly Disagree (SD), Disagree (D), Neutral (N), Agree (A), and Strongly Agree (SA).

Table 2. Pearson correlation, n = 17

<table>
<thead>
<tr>
<th></th>
<th>Δ CKA overall</th>
<th>Δ Intent to Persist</th>
<th>Δ Confidence</th>
<th>Δ Enjoyment</th>
<th>Δ Importance &amp; Perceived Usefulness</th>
<th>Δ Motivation</th>
<th>Δ Identity &amp; Belongingness</th>
<th>Δ Creativity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Δ CKA overall</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δ Intent to Persist</td>
<td>.083</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δ Confidence</td>
<td>-.175</td>
<td>.583*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δ Enjoyment</td>
<td>.282</td>
<td>.093</td>
<td>.540*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δ Importance &amp; Perceived Usefulness</td>
<td>.365</td>
<td>.366</td>
<td>.628**</td>
<td>.912**</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δ Motivation</td>
<td>-.149</td>
<td>.431</td>
<td>.574*</td>
<td>.408</td>
<td>.364</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δ Identity &amp; Belongingness</td>
<td>.139</td>
<td>.740**</td>
<td>.815**</td>
<td>.646**</td>
<td>.839**</td>
<td>.507*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δ Creativity</td>
<td>-.242</td>
<td>.780**</td>
<td>.775**</td>
<td>.191</td>
<td>.333</td>
<td>.611**</td>
<td>.691**</td>
<td></td>
</tr>
</tbody>
</table>

**p<.01; *p<.05. Δ = Now-Before
To further investigate how the EarSketch program impacted students’ intent to persist in computing, a correlation analysis was conducted whereby the change in responses (Δ) from Before to Now across the 7 survey constructs listed in Table 1 were entered into a Pearson’s correlation. The results, presented in Table 2, indicate that to the extent that students gained in confidence, belongingness and creativity, their intent to persist in computing increased. Interestingly, growth in creativity was statistically significantly correlated with growth in confidence, motivation and belongingness. Further, the data indicate no significant correlation between a change in content knowledge and a change in the engagement constructs.

Figure 4 summarizes students’ gains in content knowledge across all content knowledge assessment items, specifically examining content knowledge gains by item difficulty. The results clearly suggest that the workshop was statistically significantly effective in enhancing students’ knowledge of programming concepts. Gains from pre to post were most evident for easy and moderate items. Though fewer students correctly answered the items that were rated as being hard, the results nonetheless show a statistically significant increase. The number of correctly answered content knowledge assessment items were also examined per individual student. On average, students made a 4 item gain from pre to post; that is, the average student answered 6 questions correctly at post and only 2 questions at pre. Perfect scores (10 out of 10) at post were found among two students. Further, female students made, on average, a 5-item gain from pre to post, and male students made a 4-item gain.

**Figure 4. Pre/Post content knowledge assessment items by difficulty**

When asked what aspects of the workshop students enjoyed the most, the vast majority indicated that they appreciated learning about programming and working on complex and interesting projects in computing and music. For example, one student noted that “the best thing about this camp was the fact that we were introduced to programming, while also integrating it into musical concepts.” Another student expresses her enthusiasm for the workshop projects by saying, “Learning how to create music using only code with minimal help from a DAW was very exciting and interesting. The code allows for a much easier and faster way to mix and remix music.” Other aspects of the workshop that students valued were the supportive and positive environment created by the staff and the fellow campers.

5. RELATED WORK

5.1 Motivation

Learning how to program is a challenging task in itself, and there is a long history of research into building different types of programming environments intended to make computer science more accessible to a broader audience [13]. Much of this work has focused on targeting specific groups, such as women [23] and minorities [7,9,10,29] or leveraging interest in other areas, such as digital games [18,21,24], textiles [2], and music [16,17]. Particularly with respect to digital media, the hope is that a large and more diverse audience will be more interested in the creation of media-related content (as opposed to programming for its own merits). Because a novice audience will likely not have existing programming skills, these tools are intended to bridge the gap while maintaining students’ attention.

5.2 Remixing Media

When remixing, musicians “weave samples from familiar songs into a new montage of sound,” sampling melodic and harmonic riffs from existing recordings to create the rhythmic foundation for a new work [26]. This practice, which leverages creating, sharing, and listening to music as a potentially more ubiquitous cultural practice than seen in other computing educational domains, will serve as motivation for many students to program. Hip hop music, which we focus on as a means of engaging African-American students in particular (though hip hop is itself a widely popular domain), has already been successfully used as a culturally motivating domain in the recruitment of middle school students into computing in high school and beyond in coursework at North Carolina A&T State University (unpublished), for pre-computational education [7,9,10], as well as in other non-computational domains, such as reading [19,20].

6. FUTURE WORK

We continue to iteratively review, refine, and evaluate all three components of EarSketch (curriculum, software toolset, and social network) as we prepare for a public release and broader deployment of the project. Near-term plans include a six-week pilot at an ethnically and socioeconomically diverse public high school in metro Atlanta in early 2013, to assess the success of our workshop curriculum in a more formal academic setting; and a two-week summer workshop in 2013 at Georgia Tech’s Institute for Computing Education, to pilot additional curriculum modules focusing on more advanced computing and musical concepts. As the number of students participating in EarSketch pilots grows, we also hope to obtain statistically significant data about the learning outcomes and attitudes changes in students of different demographic backgrounds, so that we can better understand the impact of EarSketch on computing education for various under-represented populations.

We are also adding new functionality to the EarSketch software toolset and social media website. Some of our development is focused on improving usability and the seamless integration of multiple software components through changes such as new EarSketch menu items within Reaper and a cleaner project metadata entry page on the social media website. Other changes focus on new API functionality for the software toolset, in particular on functions to analyze sections of existing tracks or audio files and to design new effects to transform audio. This additional functionality will expand the creative possibilities of the environment, support the use of new computing concepts such as conditionals, and help make the toolset practical for use in more extended courses at the high school or college level. Finally,
we are in the process of replacing the existing library of audio loops bundled with EarSketch, which were licensed to us only for use in pilot studies, with a more openly licensed library of audio content. This is a prerequisite to public dissemination and broad deployment of EarSketch.

7. REFERENCES