Leveraging Prior Computing and Music Experience for Situational Interest Formation

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ABSTRACT

Computer science educators often use multiple creative computing platforms to motivate and support students learning computer science. Arguably, we understand little about the complementary ways in which the various platforms build on students' prior experiences. This study compares two CS+music platforms used by middle school students in a summer camp to understand the unique affordances of each platform at activating and building upon prior music and computing experiences. We assess interest formation through pre and post student surveys and via interviews on the final day of the camp. The findings suggest that using different approaches to CS+music platform design may help engage students with different levels of prior music and coding experience.

CCS CONCEPTS

• Social and professional topics~Computational thinking • Social and professional topics~K-12 education

KEYWORDS

Computer science education; CS+music; music; STEAM; interest; broadening participation; summer camp; informal learning

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1 Introduction

Ample evidence suggests music's unique potential to engage broad populations of students in introductory computer science learning experiences [18]. In recent years, numerous computing education platforms have combined music and coding [14][10][1]. It is reasonable to expect that different CS+music platforms will have different affordances, which might reveal important distinctions in terms of student interest formation in both domains. It is important, therefore, to understand the differing affordances of these and other platforms in how they structure musical and computational creation [4], how they connect music and coding together, and how--as a result--they engage students differently based on their prior music and computing experience and interests.

By analyzing the affordances of these learning platforms, educators and curriculum developers can tailor learning interventions to their students and learning goals and, we hope, achieve better student outcomes.

1.1 EarSketch and TunePad

This paper compares the affordances of two complementary platforms that use musical expression as a motivator to learn coding, describes their use together in an online summer camp for middle schoolers, and analyzes data collected from the summer camp on interest formation among groups of participants.

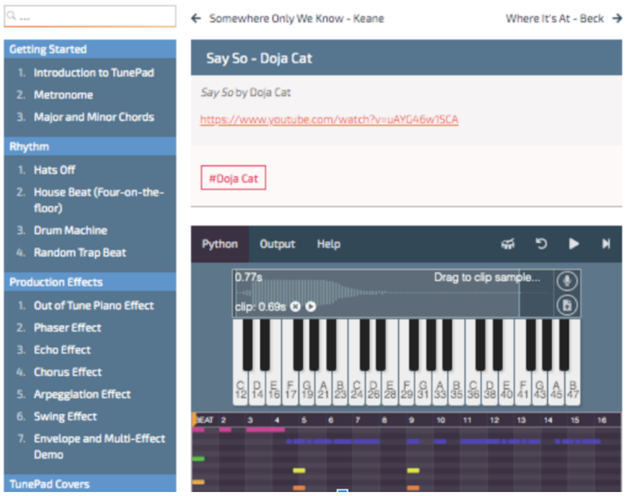

Figure 1: A screenshot of the TunePad web application.

The first platform, TunePad (Figure 1), uses a bottom-up approach in which students write code to create songs out of individual musical elements (i.e. notes and rests), connecting these musical elements into longer sequences of music. In this manner, TunePad references the music theory concepts already in widespread use in K-12 bands, orchestras, and choirs[19][20]. The second platform, EarSketch (Figure 2), uses a top-down approach akin to remixing, starting with phrase-length samples that can be broken up or sequenced together. In EarSketch, students write code to arrange short, pre-existing audio loops and effects on a multi-track timeline to create a complete song. EarSketch's approach aligns with the popular music practices of sampling, remixing, and music production, and more readily allows those without formal musical training to easily create music.

Through this study, we hope to understand how the differing affordances of the two platforms correlate with differences in situational interest development. How does each platform affect student interest in making music with code? In attempting to answer this question, we hope to share insights into the differing strengths and best use cases for EarSketch and TunePad. We also wish to highlight that the adoption of any creative computing platform must be accompanied by insight into how the creative and computing affordances of the platform dovetail with students' experiences and interests.

2 AFFORDANCES

Educational affordances are the properties of an educational intervention that enable particular kinds of learning [7]. In this study, affordances are the characteristics of CS+music platforms that invite students to apply prior learning to new learning experiences. EarSketch and TunePad approach computational music-making from two different perspectives. TunePad's approach is "bottom-up;" students build music from constituent notes (pitches and rhythms) and assign these to different instruments in order to realize a complete musical "idea."

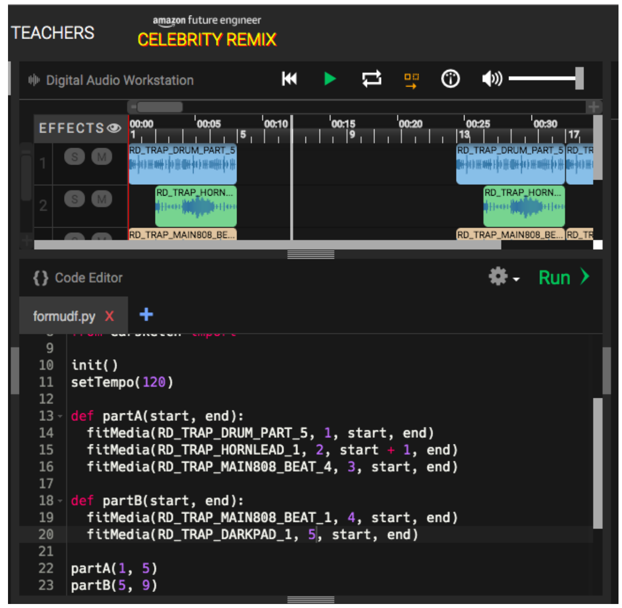

Figure 2: A screenshot of the EarSketch application.

EarSketch's is "top-down;" students use pre-made segments of music and then remix, recombine, and apply effects to create a new, composite musical work. Both approaches are used in professional practice; however, TunePad invites a more classical approach to music making commonly found in music theory, music education and learning an instrument while EarSketch affords a studio production approach that uses sampling and remixing.

The two platforms also differ in their approaches to making music through code. TunePad's most commonly-used function, `playNote()`, plays a single musical note at a specified pitch and duration. In TunePad, students must understand the basics of music theory, so that they string together sequences of `playNote` functions to create a musical riff in a coherent key and meter. For students with even a rudimentary musical background, these musical building blocks are familiar (along with the musical keyboard that pervades TunePad's interface). For those who are new to music theory, the TunePad curriculum introduces these concepts just-in-time as they are needed to create music in the platform.

EarSketch, in contrast, steadfastly avoids reference to any music theory concepts that may be unfamiliar to students with no prior training. Its primary API function, `fitMedia()`, places a pre-recorded musical loop at a designated location on the multi-track timeline. Students create songs out of multi-measure loops rather than single musical notes. The curriculum introduces large-scale musical concepts like form, transitions, and tempo but never addresses low-level concepts like pitch. Instead of referencing music notation or musical instruments, EarSketch references music production practices.

TunePad and EarSketch also differ in their computing affordances. While both platforms focus on a similar set of computing concepts (variables, functions, loops, conditionals, and lists), EarSketch follows Carroll's dictive to provide students an "immediate opportunity to act" [2] and prioritizes the ability of students to create complete, high-quality songs from the first moments of use. This approach has been shown to highly engage students but also risks focusing their attention so much on music-making that it comes at the expense of computational learning [12]. In TunePad, it is just as easy to create something quickly, but it takes students much more effort to get to a complete, polished song. This may, though, encourage students to incorporate more complex computational constructs into their code at an earlier stage.

Despite these differences, both platforms are intended for students with no prior background in either music or coding, and both are designed to provide low floors and high ceilings [14][16]: students can create music with a few lines of code and also build complex multi-track songs.

3 Related Work

The past two decades have seen growth in learning interventions that combine computing with artistic expression, acknowledging that computing and aesthetics are integral to students' lives [8]. Implementing interventions with novice learners can be challenging; students' ability to create music with code is limited by a lack of music theory and computing fundamentals necessary to realize musical goals [14].

CS+music pedagogical platforms have taken varied approaches to enable students to easily create computational music. From a musical perspective, APIs tend to focus either on playback of pre-recorded sounds (EarSketch, AgentSheets, Alice) or on the note-by-note creation of melodies [15]. Many platforms, such as Scratch, offer both functionalities. Triggering and looping pre-recorded sounds requires no specialized musical knowledge, but it can be challenging to combine multiple sounds together in a musically coherent way that is rhythmically, harmonically, and stylistically consistent. Note-by-note creation offers students more control but often demands prior musical knowledge.

Computational Remixing [5][15] is a third approach used by platforms like EarSketch which combines a multi-track audio environment with coding for rule-based playback. This approach references techniques used in recording studios, popular music, and consumer music applications. It also supports musical coherency when combining audio files (e.g. time stretching to common tempo, sound libraries organized by genre and key, and a timeline view) without the need for high domain-level knowledge in music.

4 Summer Camp Pedagogy

The authors, along with colleagues from Northwestern University, developed a summer camp curriculum using TunePad and EarSketch. While originally developed for an in-person camp, the onset of COVID-19 forced the camp to a virtual camp setting. The development of the Coded Beats curriculum was guided by a constructivist perspective [13]. If students had taken computer science courses before or were involved in music ensembles, they were encouraged to use their previous knowledge. The overall structure was similar to Robert Karplus's three-stage model [13]. While multiple versions exist, we used: **Stage 1) Exploration** (sessions started by giving students time to explore the platforms on their own); **Stage 2) Term Introduction** (we introduced CS concepts with demonstrations showing how the concepts are applied in scripts and reinforced vocabulary used in making music with code); and **Stage 3) Concept Application** (students applied what they learned to their own projects). The summer camp explicitly focused on five computing concepts (user-defined functions, loops, variables, lists, and strings).

5 Interest Formation

We apply Hidi and Reninger's [6] model of interest development, and the four phases of the model include: **1) Triggered Situational Interest**; **2) Maintained Situational Interest**; **3) Emerging Individual Interest**; and **4) Well-Developed Individual Interest**.

Given the short time-frame of the learning intervention, this analysis focuses specifically on phase 1 with an eye toward moving students into phase 2. We measure the affective/cognitive features of triggered situational interest. Hidi and Reninger [6] explain that students move from triggered to maintained situational interest because they find the object of interest to be meaningful; therefore, we also measure personal relevance as a necessary ingredient for moving students to phase 2.

Hidi and Reninger [6] define triggered situational interest as a context-specific and spontaneous psychological state. As the first stage of interest formation, it precedes individual interest which is enduring and context-general. Situational interest includes focused attention and an affective reaction triggered in the moment by stimuli in the environment. Situational interest may or may not last over time while individual interest is a relatively enduring predisposition to reengage with the object of interest.

With both triggered and maintained situational interest in mind, the curriculum focused on open-ended music projects with genres and themes selected by students. We also polled students on their favorite music, used multiple types of media including student-selected media, and conducted activities that provided an easy way for students to get involved (group discussions, breakout groups, online polls, discussion boards, an online computational drum circle, and a collaborative online bulletin board) while supplying diverse modes of creative musical expression.

6 METHODS

To better understand the implications of the different affordances of TunePad and EarSketch on situational interest formation, we studied a virtual, one-week deployment of the Coded Beats summer camp for middle school students in Georgia. It was taught by an accomplished high-school CS teacher who had prior experience teaching EarSketch but was new to TunePad and the Coded Beats curriculum. The instructor was assisted by one of the authors along with administrative staff from Georgia Tech's CEISMC (Center for Education Integrating Science, Mathematics and Computing). The camp used video conferencing software and a learning management system to facilitate online delivery.

The camp took place for four hours each day for five consecutive days. The two hours each morning focused on exploration of the platforms (TunePad or EarSketch) and introduction to key music and computing concepts. During the two-hour afternoon sessions, students had time to creatively apply the information they learned during the morning session to their own projects.

The first two days focused on TunePad; the third and fourth days focused on EarSketch. On the last day, students finalized their projects for a closing showcase. For their final projects, students could use TunePad, EarSketch, or a combination of both platforms to create their new piece of music.

6.1 Quantitative Methods

This study examines learning affordances through pre and post surveys and student interviews. Pre-surveys were collected on the first day and asked students about their prior experience, enjoyment, and confidence in coding and music making. The post survey measured triggered situational interest, maintained situational interest, and attitudes toward computing. The constructs and items are derived from [3][9].

Six constructs are used to assess triggered situational interest [3]. The first three constructs focus on creating music with code independent of platform: **1) Novelty** (the gap between what is known and unknown; a state eliciting exploratory behavior); **2) Challenge** (the level of difficulty relative to one's ability); and **3) Instant Enjoyment** (immediate perception of situational interest; may increase intrinsic motivation).

The next three subconstructs ask students to differentiate their experience by platform (see Table 1): **1) Exploration Intention** (the power of stimulation observed in puzzles, brain teasers, and "weird" mathematical problems [11]; **2) Attention Demand** (related to flow, the extent to which the object of interest draws the participants' attention); and **3) Instant Enjoyment** (immediate perception of situational interest; may increase intrinsic motivation to engage).

6.2 Qualitative Methods

Fifteen students participated in 20-minute semi-structured interviews on the final day of the camp. Interviews were recorded and transcribed verbatim. The first cycle of coding involved assigning attribute codes (gender, race/ethnicity, age, identity [coder, musician, hybrid] and structural codes (conceptual phrases related to the research questions and discussion with participants) to the corpus. In the second cycle of coding, pattern and focused coding was used to develop group similar experiences and views of EarSketch and TunePad to identify the themes and explanations of students' experiences with each platform [17]. After completing the second cycle of coding, the lead qualitative researcher engaged one of the co-authors, an instructor and expert in music composition, to provide clarity to students' responses related to the music elements and experiences in the camp.

7 RESULTS

7.1 Participant Demographics

In May, 2020, 41 students registered for the Coded Beats Summer Camp, and 26 participants consented. The consented students generated 63 usable projects; unusable projects are those which were copied from instructional scripts or were projects with no code. Of the 63 usable projects, 32 were EarSketch projects, and 31 were created in TunePad. Participants ranged in age from 10 to 14 (M = 12.04; SD = 1.11); seven (27%) identified as female, and 19 (73%) identified as male. Five (19%) participants were Black; eight (31%) were Asian; 11 (42%) were White, and the remainder either did not answer or were below the reporting threshold. We also collected free/reduced price lunch status from students as a measure of socioeconomic status; 19 participants (73%) indicated they are not eligible, two (8%) were eligible but did not participate, and the remaining declined to answer.

7.2 Musicians, Coders, and Hybrids

Based on findings from the pre-survey, three distinct participant groups emerged: musicians, coders, and hybrids. We operationalize the groups with six items from the pre-survey. Participants in the "coders" category Agree or Strongly Agree on two items ("I have a lot of self-confidence when it comes to coding" and "I enjoy coding") and indicate that they have taken at least one other programming course.

Item	Group	EarSketch	TunePad
Construct: Exploration Intention			
1. I want to discover all the features of [platform].	Coders	3.75	3.12
	Musicians	3.67	4.11
	Hybrids	4.50	3.89
2. I want to analyze [platform] to have a grasp on how it works.	Coders	3.88	3.25
	Musicians	3.67	4.00
	Hybrids	4.50**	3.56**
Construct: Attention Demand			
3. I concentrated while using [platform].	Coders	4.00	3.88
	Musicians	4.11	4.44
	Hybrids	4.75*	4.11*
4. I was focused while using [platform].	Coders	4.00	3.71
	Musicians	4.22	4.33
	Hybrids	4.62	4.11
Construct: Instant Enjoyment by Platform			
5. Creating music with code was exciting with [platform].	Coders	4.00	3.62
	Musicians	4.11	4.11
	Hybrids	4.62	3.67
6. Creating music with code was enjoyable with [platform].	Coders	4.12	3.88
	Musicians	3.89	4.22
	Hybrids	4.75	4.11

Note: *p<.05; **p<.01; Statistical test performed: Wilcoxon rank-sum test; Scale: 1=Very Untrue, 2=Untrue, 3=Neutral, 4=True, 5=Very True. Interpret with caution given the relatively low n for each participant group (Coders n=8; Musicians n=9; Hybrids n=9).

Participants in the "musician" category Agree or Strongly Agree on two items ("I have a lot of self-confidence when it comes to making music" and "I enjoy making music") and indicate that they have taken instrument lessons. No participant met all six criteria, and the music and coding students did not overlap. The remaining students, hybrids, do not fit into either extreme but possess qualities of both.

Table 1: Triggered Situational Interest by Platform and Student Group

7.3 Interest Formation

Among all participants, the results indicate no significant difference between the two platforms for exploration intention, attention demand, and instant enjoyment. An analysis by student group shows that coders consistently report greater exploration, attention, and enjoyment for EarSketch while musicians report greater or equal values across all constructs for TunePad. Hybrid students express the greatest difference between the two platforms indicating that EarSketch may promote greater triggered situational interest among hybrid students.

The primary difference between triggered and maintained situational interest is that the participant finds the experience to be personally meaningful, a necessary quality of the experience for a participant to return to the object of interest. We measure personal meaningfulness for both programming and music for both platforms using the four items in Table 2. Among all participants, we noticed no significant difference between EarSketch and TunePad; however, when looking at individual groups, we see that: Musicians ranked TunePad equally or higher on each item; Coders followed the same pattern on three of the four items; and Hybrids favored EarSketch on all items and on the only significant item.

Item	Group	EarSketch	TunePad
1. [platform] allows me to work on MUSIC projects that are meaningful to me.	Coders	4.25	4.25
	Musicians	4.33	4.44
	Hybrids	4.78	4.11
2. [platform] allows me to create MUSIC that I am proud of.	Coders	4.38	4.57
	Musicians	4.56	4.56
	Hybrids	4.78	4.22
3. [platform] allows me to work on PROGRAMMING projects that are meaningful to me.	Coders	4.38	4.62
	Musicians	4.44	4.78
	Hybrids	4.78	4.33
4. [platform] allows me to create COMPUTER PROGRAMS that I am proud of.	Coders	4.50	4.25
	Musicians	4.44	4.78
	Hybrids	4.78*	3.78*

Note: Scale: 1=Never, 2=Rarely, 3=Every once in a while, 4=Sometimes, 5=Almost Always. * = $p < .05$. Interpret with caution given the relatively low n for each participant group (Coders n=8; Musicians n=9; Hybrids n=9).

Table 2: Maintained Situational Interest by Platform and Student Group

This section looks at the first two phases of interest formation (triggered situational interest and maintained situational interest) and suggests that the platform may affect interest formation differently among different groups. Musicians report higher triggered and maintained situational interest through TunePad while Hybrid students report higher triggered and maintained situational interest via EarSketch. Coders were more complex; they report higher triggered situational interest from EarSketch but higher maintained situational interest via TunePad.

7.4 Qualitative Findings

In one-on-one interviews, participants shared their perceptions of the differences between EarSketch and TunePad. Many of the comparisons reinforced the "bottom-up" approach of TunePad and the "top-down" approach of EarSketch. A 14-year old male musician highlighted the ability to make music from scratch in TunePad: "*This little drum beat right here, I did that building up and I made that myself because I couldn't find anything like it in EarSketch. So, if I couldn't find anything, I went and made it.*" A 14-year old female musician reinforced this idea: "*So in TunePad, you can actually create your own beat and song or melody, like using different instruments.*"

Other students preferred the ability to combine pre-recorded sounds to make a song in EarSketch. A 10-year old male hybrid criticized TunePad along these lines: "*There weren't soundtracks, like that you could use that were already put together and there was a limited amount of instruments.*" A 12-year-old male hybrid shared that in EarSketch, "*it sounds like an actual song, rather than just notes.*" And an 11-year old male coder said that "*I knew how to make a song mostly and I just didn't know what to make. But on EarSketch there were a lot of pre-made tunes that you could just put together and it sounded really good.*" Students also appreciated the wide variety of pre-made content available, as an 11 year-old female musician said: *"There's so many genres of sound you have everything from gospel to UK house and that's just something that TunePad doesn't have...And there are so many collections too."* Not only did students feel that EarSketch was easier for creating full songs; they also felt that the resulting music was more complex, as a 13-year old female hybrid explains: "*I was able to take the music to the next level instead of it being basic, I can make it more advanced and complicated.*" But that easy ability to create a full song also meant less control over the low-level details, as a 14-year-old female musician noted: "*And they both have different things, TunePad and EarSketch. Like EarSketch, you... I don't think you could make your own beat or something. You can upload, but yeah.*"

8 Discussion

This small-scale study comes with numerous caveats attached to its findings. We studied a single, one-week virtual summer camp with a relatively small number of participants. The camp curriculum covered only basic introductory concepts in both music and computing on both platforms. The two platforms were introduced in a particular order (TunePad first, EarSketch second). It is also sometimes unclear whether differences observed are the result of distinctions in the two platforms or in the way they were covered in the camp curriculum.

Nonetheless, these findings together tell an intriguing story about the possible implications of "top-down" and "bottom-up" designs (and of loop-based audio vs. note-based paradigms) in CS+music learning platforms. The findings show higher triggered and situational interest formation for musicians through TunePad, suggesting that the bottom-up, note-based approach to computational music may have helped foster interest formation by connecting to their prior music experience and mimicking familiar music paradigms. The hybrid students, whose music experience was likely less extensive, showed higher triggered and situational interest formation with EarSketch; its top-down, audio-based remixing approach did not rely on these musical concepts and had an easier path to quickly creating full songs. The coders reported higher triggered situational interest from EarSketch but higher maintained situational interest via TunePad. In interviews, musicians consistently connected their preference for TunePad to its bottom-up approach ("create your own beat and song or melody"), while hybrid and coder students consistently cited top-down aspects of EarSketch as the reasons behind their preferences for that platform ("pre-made tunes that you could just put together and it sounded really good").

Because students with different backgrounds responded differently to the two platforms in terms of situational interest, it may be beneficial to align choices for CS+music platforms to students' prior experiences in both domains or to introduce multiple platforms to groups with heterogeneous prior experiences. For coders, the two platforms had different strengths with respect to stages of situational interest formation, suggesting possible benefits of using multiple platforms even with homogeneous groups. Sequencing of platforms may also be important to consider. Though the camp introduced TunePad first, EarSketch's role in triggered situational interest for coders suggests there may be benefits to reversing the order of the platforms in a future iteration.

Through this study, we have learned how top-down, loop-based and bottom-up, note-based approaches to CS+music learning platforms have different and complementary roles in situational interest formation for students with varying prior experiences in music and coding. The findings suggest that tool developers, curriculum providers, and educators should carefully consider the prior experiences of students and select a combination of creative computing interventions designed to foster situational interest for those students. In future studies, we hope to analyze the use of TunePad and EarSketch across a wider range of learning contexts -- including longer-duration experiences -- to better understand the complementary roles the platforms play in engaging students in computing and the most effective ways in which to teach them together. We also intend to analyze the artifacts that students create — their EarSketch and TunePad projects — through a multidimensional analysis of music complexity and code complexity. Through such an analysis, we hope to explore how coder, musician, and hybrid students demonstrate mastery of musical and computational concepts differently across the two platforms.

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https://earsketch.gatech.edu/earsketch2/.
TunePad is available at http://tunepad.live.

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