A Case Study of Middle Schoolers' Use of Computational Thinking Concepts and Practices during Coded Music Composition




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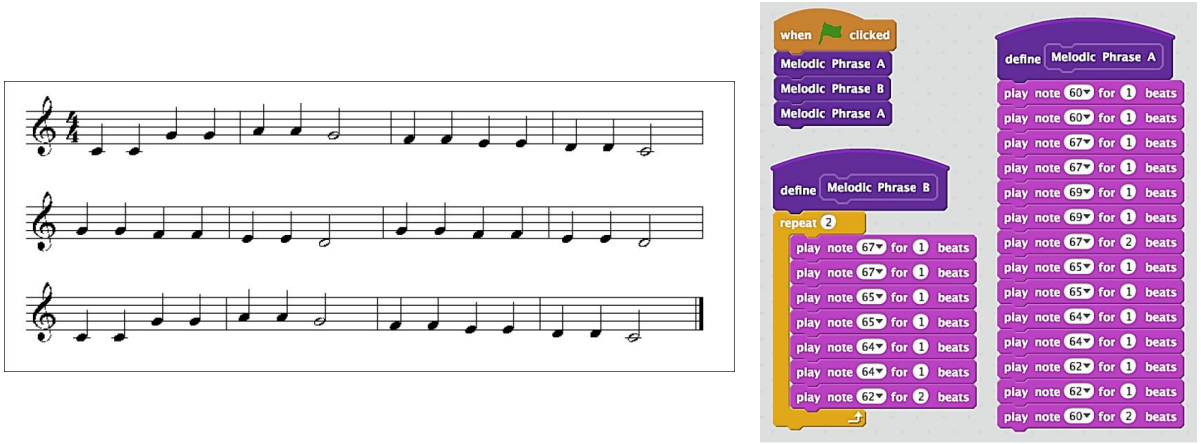
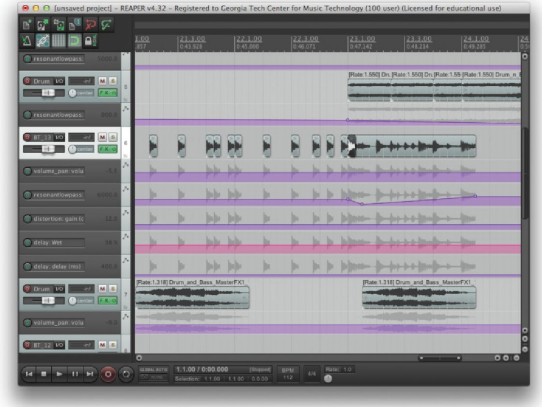
Teaching Computational Thinking (CT) with Music

- The integration of music and CT is particularly promising [Baratè et al., 2017; Bell and Bell, 2018; Petrie, 2021]

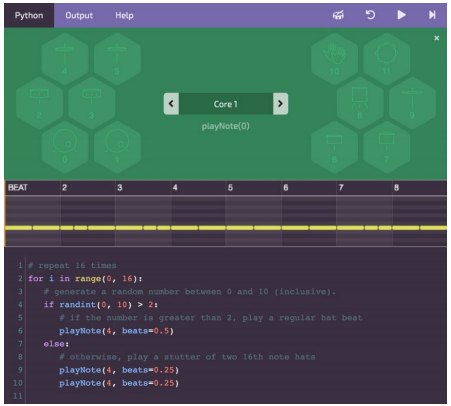


Twinkle Twinkle Little Star in Common Music Notation (left) and in Scratch (right) [Bell and Bell, 2018]

Supported by Music Coding Environments

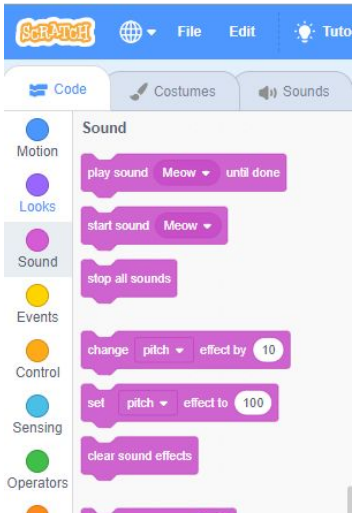


EarSketch, Python, remixing music
[Magerko et al., 2019]



TunePad, Python, interactive web-based
[Horn et al., 2020]

Sonic Pi, Ruby, live coding
[Aaron, 2016]



Scratch, Block-based
[Resnick et al., 2009;
Greher and Heines, 2014]

And, Curricula for Integrating Music & CT

- Media computation course for university non-majors [Guzdial, 2003]
- Coding exercises for middle school students in Blockly [Baratè et al., 2017]
- Connect CT and music with K-12 students in Scratch [Bell and Bell, 2018]
- Code Beats, teaches middle school students to program using Sonic Pi and more recently, TunePad [Krug et al., 2021; this paper]

Research Studies on Music & CT Integration

- Demonstration of CT [Petrie, 2021]
- Engagement [Engelman et al., 2017; Freeman et al., 2019; Jamshidi and Marghitu, 2019]
- Creativity [Engelman et al., 2017; Freeman et al., 2019]
- Affective outcomes [McKlin et al., 2019; Köppe 2020; Burnard et al., 2016]
- Better student performance and reduced course dropout rate [Tarversaro et al., 2020]

CT = Concepts + Practices

- Researchers highly recommend examining CT concepts and practices simultaneously
  [Brennan and Resnick, 2012; Zhang and Nouri, 2019; Allsop, 2019; Horst et al., 2020]
- However, research focusing on CT concepts and practices during integration of CT and music is lacking

Concepts	Practices
● **Sequences** ● **Loops** ● **Parallelism** ● **Data** ● Events ● Conditionals ● Operators	● **Being incremental and iterative** ● **Testing and debugging** ● Reusing and remixing ● Abstracting and modularizing

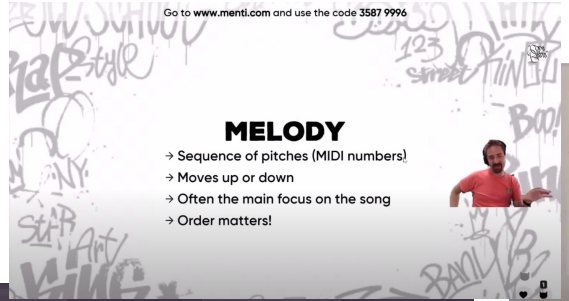
[Brennan and Resnick, 2012]

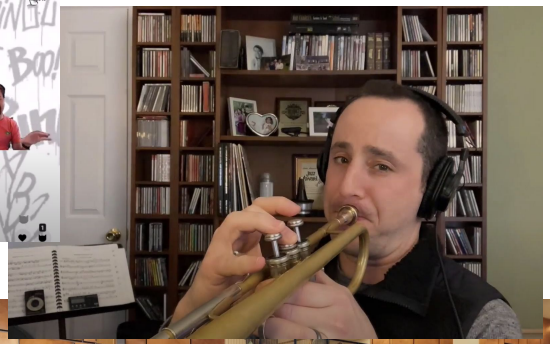
Our Contribution

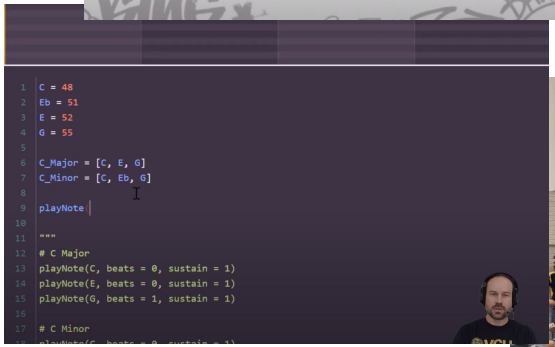
- First to analyze process logs to explore CT practices during integrated music & CT learning in K-12
  - Focus on tinkering behaviors
- Also analyzed coding products to identify CT concepts during music coding

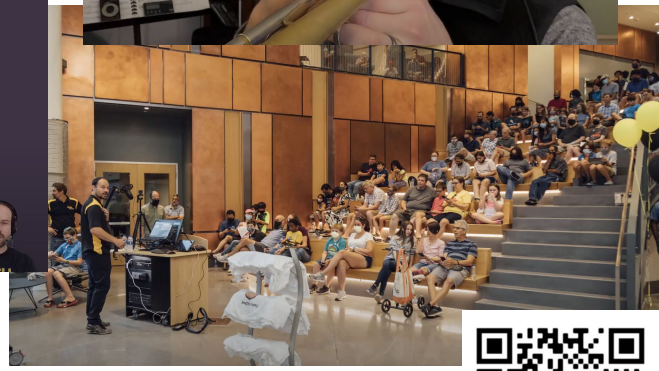
Our Study Context: Code Beats Camp

- 2-week (10 days) summer camp
- 1-hour online streamed learning session
- 1-hour office hour
- Open-ended after-class programming assignments
- Capstone project competition



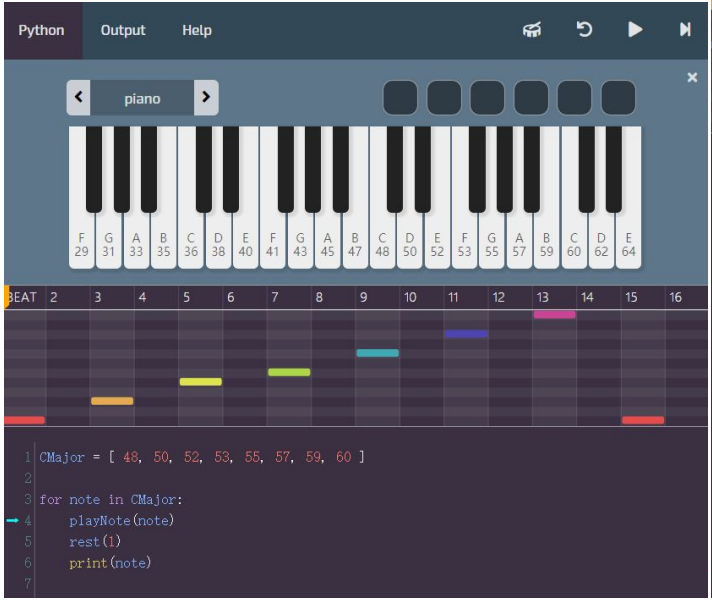


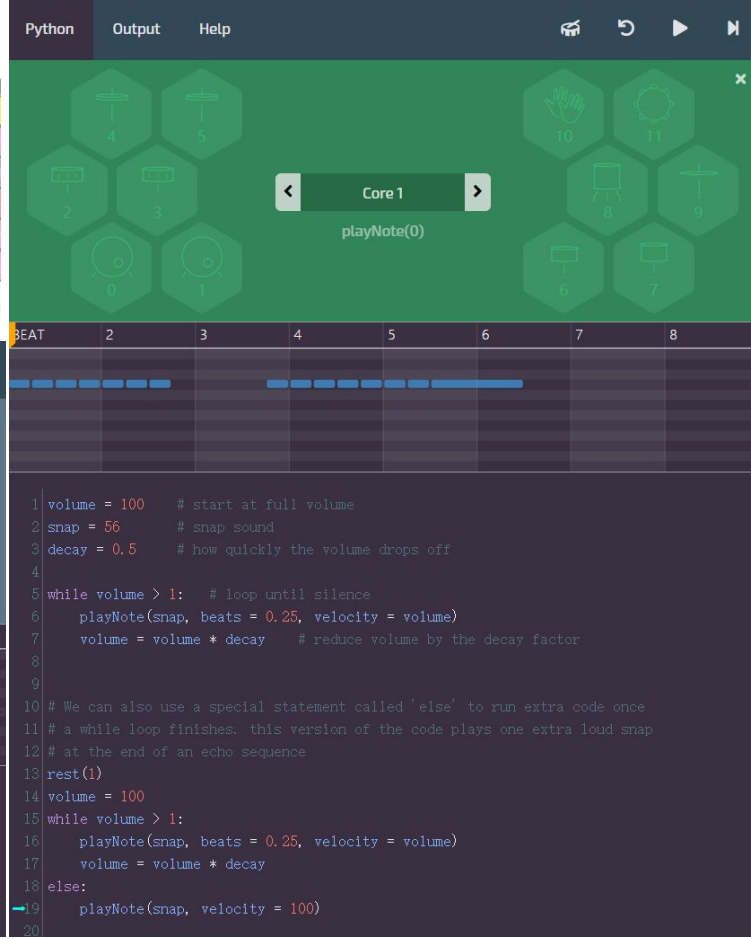




TunePad

www.tunepad.live





Case Study Activity Focus

- Day 5, day 8, and capstone projects
- Day 5
  - Given a song with 8 background instruments
  - Create 2 more instruments
- Day 8
  - Given a song with 6 background instruments
  - Create 2 more instruments

Category	Items	Day 5	Day 8
Coding Concepts	Lists	√	
	Repetition with nested lists		√
Music Concepts	Chords	√	
	Chord progression		√
CT Concepts	Sequence	√	√
	Parallelism	√	√
	Data	√	√
	Loop		√
Task Requirements	Define 4 new chords	√	
	Use given chords		√
	Each measure has 4 beats	√	√
Task Recommendations	Play recommended chords for each measure	√	
	Use *for* with *lists* to create a melody		√

Research Questions

- RQ1: What CT concepts are evident in participants' coding products? What percentage of participants met the requirements and recommendations of daily activities?
- RQ2: What CT practices, in the form of tinkering behaviors, were exhibited in participants' process logs during music coding in daily activities?
- RQ3: How did participants' tinkering behaviors during daily tasks compare with their tinkering behaviors during the final competition capstone task?

Data Collection

- 195 enrolled, **132** consented as participants
- Collaborated with TunePad developer to log coding process data
- Logged **138,735 coding events** and associated code snapshots over consented participants
  - *edit-instrument*
  - *error-instrument*
  - *play-instrument*
  - *play-project*
- Line-based granularity

	# of participants	# of events logged
Overall	132	138,735
Day 5	22	2,260
Day 8	16	1,459
Capstone project	14	21,110

Data Analysis

- *RQ1: What CT concepts are evident in participants' coding products? What percentage of participants met the requirements and recommendations of daily activities?*
- Developed metrics based on requirements and recommendations
- Examine code products

RQ1 Findings

- Majority showed success in defining (even nested) chords/lists and using given chords/lists
- Only 10-50% ensured the required 4 beats in each measure
  - We observed evidence of exploration in RQ2
  - Maybe caused by creativity of music
- Over half used loops when recommended

Concept	Require/Recommend	Num of Participants			
		Day 5 (n = 22)		Day 8 (n = 16)	
Note (Variable)	Define new notes		0		1 (6.3%)
	Change notes		1 (4.5%)		0
Chord (List)	Define required chords	R	15 (68.2%)		
	Define nested chords				10 (62.5%)
	Use given chords			R	15 (93.8%)
	Play recommend chords	C	7 (31.8%)		
Function	4 beats in each measure	R	2 (9.1%)	R	8 (50%)
	1-5 functions called		7 (31.8%)		
	6-10 functions called		4 (18.2%)		
	11-15 functions called		4 (18.2%)		
	15+ functions called		7 (31.8%)		
	0 function changed		14 (63.6%)		
	1-2 functions changed		7 (31.8%)		
	3+ functions changed		1 (4.5%)		
Loop	Use loop			C	9 (56.3%)

Data Analysis

- *RQ2: What CT practices, in the form of tinkering behaviors, were exhibited in participants' process logs during music coding in daily activities?*

- *RQ3: How did participants' tinkering behaviors during daily tasks compare with their tinkering behaviors during the final competition capstone task?*

Tinkering behaviors [Dong et al., 2019]

- **Construction-based tinkering**
- **Test-based tinkering**
- Prototype-based tinkering

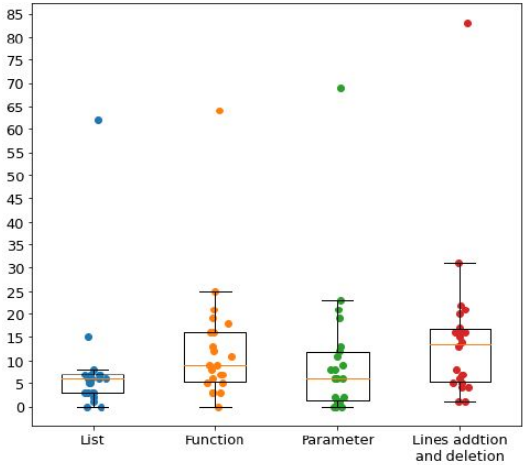
Data Analysis

- **Construction-based tinkering**
  - Token changes, including *list, function, parameter,* and *loop*
  - Adding or deleting lines of code
  - More changes, more construction-based tinkering
- **Test-based tinkering**
  - Number of edits between plays (i.e., code executions)
  - Lower number of edits between plays, more test-based tinkering

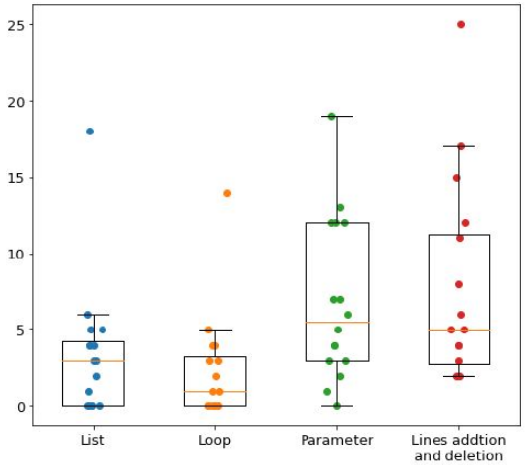
Construction-based Tinkering Findings

Number of changes per participant

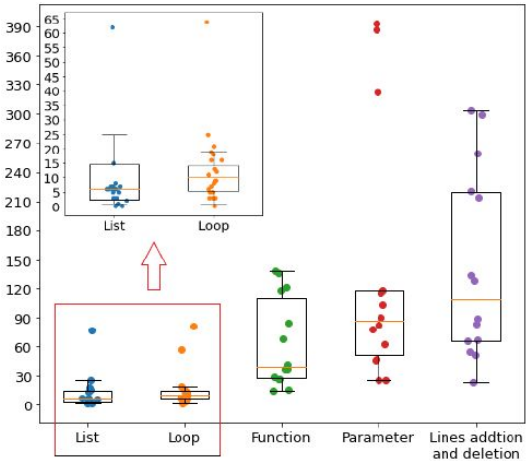
Token and number of line changes for day 5 (n=22)



Token and number of line changes for day 8 (n=16)



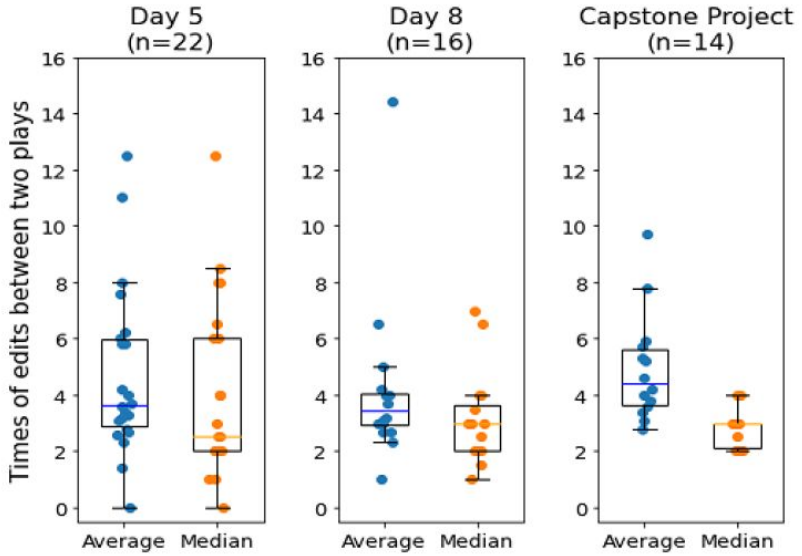
Token and number of line changes for capstone project (n=14)



- Fairly broad range of construction-based tinkering among participants
- Considerably different scale for capstone project while similar patterns among camp days and capstone project

Test-based Tinkering Findings

- The majority of participants made 3 to 5 edit events between two plays across days
- The low number of edits between plays suggests that participants were following test-based tinkering behavior



Summary of Key Findings

- CT concepts:
  - Participants showed success in defining chords/lists, using loops
  - We expected more participants to meet the requirements and recommendations during the after-class activities
  - Maybe due to the online nature of camp or creative nature of music
- CT practices:
  - Broad range of construction-based tinkering, which did not relate to gender, prior music experience or prior interests in computing
  - A major goal of our work is to broaden participation in computing, this finding is encouraging
  - All participants demonstrated some test-based tinkering with few edits between plays

Threats to Validity

- Small number of participants who actually edited code during the after-class activities
  - Mainly due to the nature of the camp: online, 1-hour, no supervision
  - Will increase that number in future in-person formats to gather more data

- Did not collect qualitative data focusing on students' thinking processes while coding
  - Coding logs may not reflect the real thinking
  - Could be mitigated using think-aloud methods

Conclusions and Future Work

- One of the first to use process logs in music coding to explore CT practices in an integrated approach to CT learning
  - Broad range of construction-based tinkering
  - Small difference in test-based tinkering with few edits between plays
- CT concepts demonstrated in student coding products
  - success in defining chords/lists, using loops
- Future work includes collecting a greater volume of process log data that may help uncover additional patterns; collecting qualitative data

- We appreciate TunePad develop team for data logging
- This paper is based upon work supported by the National Science Foundation under grants 2048793 and 2048792

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Q&A