Co-Design of Wearable Music Curriculum for Neurodiverse Computational Thinking

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***Abstract*—We develop computing practices for neurodiverse learners. While many researchers in special education adopt a behavioral perspective, we leverage a neurodiversity perspective that is more widely accepted within the autism community itself. We report on an initial phase of a research-practice partnership with a pilot cohort of four middle school teachers with whom we are co-designing embodied musical practices using networked Internet of Things (IoT) wearables with embedded inertial measurement units (IMUs). Our culturally and epistemically diverse teaching fellows work with diverse student populations (Black, Brown, Native American, neurodivergent) at Title 1 schools. The neurodiversity perspective sensitizes our co-design to tactile, kinetic, sensory, and ensemble energies that overflow neurotypical learning modalities, which typically privilege screen-based interaction, cognitivism, and isolation. We find "wearable music" to be an inclusive, mobile, and mobilizing computing approach that foregrounds embodied interactions in fun and engaging group activities surfacing computational thinking (CT). In later phases of this research, our teaching fellows will run workshops for additional educators, scaling the curriculum for implementation and evaluation in many more classrooms.**

Keywords—BPC, neurodiversity, computational thinking, embodiment, wearables, ensemble, music

I. Introduction

"Engaging Teachers and Neurodiverse Middle School Students in Tangible and Creative Computational Thinking Activities" is a three-year project (Aug. 2021 – July 2024) designed to support computing education equity for students with autism, who too often find themselves without the support needed to excel academically, socially, and creatively. This is magnified in the critical years of middle grade students and employment entry, and further exacerbated by neurotypical technologies like desktop video conferencing foregrounded by the pandemic. We are motivated by neurodiversity activism, which celebrates the interdependent, faciliatory, relational, and embodied dimensions of neurodiverse experience shaping *all* experience as fundamental aspects of social existence [1]. We contribute to computing education equity by taking neurodiversity as a baseline, developing a knowledgebase for embodied CT learning that supports students with or without autism.

CT can be understood as a "process for solving problems, designing systems and understanding human behavior, by drawing on concepts fundamental to computer science" (Wing, 2006, p. 33). The central task of CT is the formulation of problems so they can be solved through algorithmic and computational steps. We maintain that CT can be and should be a creative and embodied process, especially if it seeks to be inclusive of neurodiverse youth. To that end, we are exploring digital music as a tool for acquiring and applying computational thinking [2]. We host workshops with teachers in which we co-design musical instruments that are coupled to networked IoT wearables with embedded IMUs, adapted from our prior work in room-scale instruments, participatory workshopping, and remote learning [3,4,5,6]). In a later phase of this research, we will explore adaptation of these designs to support tangible and social affordances in telematic embodied learning.

II. Partnerships

Our research-practice partnership is a collaboration among university researchers, educators, and teaching fellows (TFs) who teach students with autism. We have hosted 3 workshops separated by an average of 4 weeks. Four teaching fellows were recruited by advertisement, resumé review, an interview, and survey. Selected fellows receive a $3000 USD stipend, funded conference travel, professional development sessions, and classroom resources. TF1 is a STEM teacher who teaches mathematics, science, and coding, and holds a BS in biomedical engineering from Columbia University and an M.Ed. in educational technology. TF2 is a Get Fit and Success coach with a BS in early childhood education and coaching from Western New Mexico University. TF3 is a music and band teacher on an Indian reservation. TF4 is a STEAM teacher and professional development facilitator for code.org and received the 2019 Arizona teacher of the year award.

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TF1 and TF2 exclusively serve students with autism; others serve students with and without autism labels. The cohort works at Title 1 schools in Phoenix, Arizona with 252 students from 3 local schools. Of these students, 203 are native American, 36 are Hispanic, 8 are African American, and 5 are Caucasian. Fifty-nine of the students have disabilities—a figure that is likely much higher, but there is no diagnosis—and 247 receive free lunch. Students represent grades 5 through 8, ages 10 to 14.

III. Workshops

Teaching fellows receive a laptop and Wi-Fi IoT wearables kit (M5Stack). Workshops are seeded with wearable instruments designed by the first author in the interpreted real-time programming environment Max MSP that embed affordances for CT activation (e.g, indexing, sorting, clocking, iteration, recursion, conditionals, arrays, probability, linear/logarithmic relationships, discrete vs. continous parameters, etc.). These instruments include "rainstick" and "clacker" metaphors as well as idiosyncratic "catapult" and "wearable jazz" instruments.

During our first workshop (6 hours), a combination of hands-on learning and technical instruction are used to introduce teaching fellows to the wearable instruments. During a didactic phase of the workshop, inquiry-based methods following the "5E" lesson plan are introduced, followed by a curriculum brainstorming session [7]. Workshop kits containing one wearable sensor are sent home with the TFs. For the second workshop (3 hours), TFs were asked to return with a short lesson they teach to the group related to their area of specialization. TF4 described using the ten-step probability table in the clacker to create a team-building collaboration among several groups of students who are tasked with recreating it through audition alone (i.e., CT pattern recognition and decomposition foci.) Patterning and imitation became predominant themes during this co-design studio session, e.g., having students listen to sounds and reproduce them through code-tracing and/or physical movement emphasizing how the body becomes the producer of sound [8]. During the third workshop, teachers were asked to report on a lesson they had implemented in their classrooms. TFs 1 and 2, who teach in the same school, reported on the use of a "Jam Stick" they created using PVC pipe and the wearable sensor:

- TF1: *"The level of engagement of the middle schoolers was really high. As soon as I turned on wearable jazz and started making music: 'Whoa, what's that!? What's that doing?!'… They really picked up on it. They got it right away… This is exactly what we wanted: create the engagement with music for students that sometimes just aren't engaged. We didn't prompt them for this; they volunteered things they could do with [the Jam Stick].*
- TF2: *He wanted to use [the Jam Stick] while he was feeling stressed…it instantly calmed him down. The harmony side of the wearable jazz…it just relaxed him so much, and it made me want to explore that more.*

For the remainder of the third workshop, new versions of the wearable instruments are introduced that are designed to work with multiple sensors (up to 4). Statistical and Boolean operators, accumulators, and windowing map movement and orientation data from multiple sensors to various features of the instruments, creating opportunities for collaborative group activities [9,10]. For the last hour of the workshop, we invited a guest artist experienced in music, dance, choreography, and early childhood education to help us explore the embodied affordances of the new group instruments. TFs took home new kits that now include 4 sensors. The response was positive:

- TF4: *"There's some cool teamwork and collaboration pieces, too, which is even beyond the computational thinking which is nice. Very cool."*

Video materials from the workshops can be accessed at this link: https://vimeo.com/showcase/9490713

IV. Discussion

Since we are in the fledgling stages of this project, our brief discussion will be focused on instrument design considerations. First, we have found it important to create instruments that can surface topics as needed in different educational environments (e.g., music theory should be available but optional). The teachers underscored how important it is for students to make these instruments "their own." Thus, instruments should have a significant degree of programmability, e.g., any sampled audio should in principle be replaceable. The ability to record improvised sound into these instruments also increases their dimensionality, offering greater potential for longer and deeper exploration and engagement. Second, with the help of our guest artist, we learned that manipulation of pitch, roll, and yaw ought to comprise the basic form of any instrument, since these are easy to explain by reference to airplanes and bring an immediate directionality to the exploratory play. Finally, a tension we are still considering is between the computational density of highly engaging instruments (such as wearable jazz) and more carefully scaffolded instruments (like the catapult). The UI of the version of wearable jazz for multiple sensors has become quite complex, and we are waiting to hear back from our teachers about their classroom experiences with this during our final workshop at the end of the year. We are also waiting to see if some of the more complex concepts (e.g., sliding windows) layered into the most recent set of instruments prompts us to reconsider the canonical hierarchy of computer science concepts.

V. Conclusion

The design plasticity and degrees of manipulative freedom of gestural music techniques better match and mediate a broader spectrum of neurodiverse learners. This also brings joy to a technology that often ignores the affective dimensions of embodied experience and creates opportunities for interpersonal motor coordination potentiating positive social outcomes [11,12]. We look forward to continuing this co-design work.

- TF4*: That's the exciting thing about [this project]: because the project is growing and the apps are growing…the students are able to influence the direction, and so you end up with something that's really going to be fruitful in the long term.*

VI. Acknowledgments

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