Vasquez, A. M., Koro, M. E., Johnson, G. L., & Amiot, D. (2023, April 16). Teacher's experiences co-designing neurodiverse pedagogies for computational thinking [Poster]. AERA Annual Meeting 2023, Division C, Section 3b.

Teachers' Experiences Co-designing Neurodiverse Pedagogies for Computational Thinking

Purpose

The purpose of this research was to study the experiences of middle-school teachers of autistic students during the co-design of neurodiverse pedagogies for computational thinking (CT) within the context of a research practitioner partnership (RPP). This knowledge building partnership was founded on the neurodiversity paradigm and challenges the assumption that individuals with disabilities are exceptions for which accommodations must be made. Neurodiversity, here, is viewed as the natural variation of neurological differences and as such is proposed to be the baseline in every educational setting (Silberman, 2016; Walker, n.d.). When neurodiversity is seen as a baseline for an educational community, the focus is on educating diverse (whole) individuals rather than planning and teaching a standard computational thinking curriculum, while adding accommodations or adaptations to meet the needs of individual students.

Our paper presents the results from a critical event analysis using qualitative data collected during the first year of a three-year mixed methods study, which includes teacher workshop mini-interviews and teacher embodied interviews. In this study, we ask: How do teachers experience the co-designing of neurodiverse pedagogies for computational thinking in a research practitioner partnership? And, how do these teachers modify and diversify their teaching practices of CT?

Perspectives

This project responds to two educational challenges: (1) Students with disabilities, particularly those with autism, experience unequal outcomes in STEM education and employment (see Roux et al., 2015; Shattuck et al., 2012), and (2) The integration of STEM education, specifically computer science education, with the arts and creative expression has too frequently gone unconsidered. Many have noted the necessity of creativity for innovation in an evolving economy, yet few have integrated creativity and the arts in the computer sciences and more broadly STEM education (see Liao, 2016). More specifically, we aimed to develop technologies and pedagogical techniques that would be sensitive to diversely embodied experiences. These teaching/learning methods were meant to appeal to innate playfulness, building CT skills as well as social and emotional capacity. Because neurotypical pedagogies, teaching methods and practices that are designed for modes of teaching/learning that fall within dominant societal norms, are not inclusive to neurodiverse students, our partnership sought to develop neurodiverse pedagogies, teaching methods and practices that are designed for multiple modes of teaching/learning, including those that fall beyond dominant societal norms. Neurodiverse modalities enhance existing educational approaches and introduce collaborative experiences that support future successful STEM employment but are often neglected in traditional approaches to CT teaching.

We aspire against settler colonial logics deeply entrenched in university research and education (Paperson, 2017; de Sousa Santos, 2015; Bhambra, 2018; 2020) by using a democratic co-design process involving educators beside researchers, thus aiming both to generate useful knowledge and rewarding classroom tools as well as insights for learning science. In this study co-design, research and pedagogical approaches include elements of embodiment, creativity, and ensemble, which extends on neurotypical pedagogies of cognitivism, linearity, and independence. We use two main embodiment strategies: manipulatives and gestures. Manipulatives have long served as a mediating device in the teaching of abstract concepts (Page, 1990). Embodied cognition research showing sensorimotor-based actions ground the teaching of abstractions (Barsalou, 2008) provide support for this practice. In fact, evidence suggests grounding abstractions in concrete examples (e.g., manipulatives) yields stronger learning outcomes (Fyfe et al., 2014). Furthermore, gestures can influence comprehension (Thompson & Massaro, 1994), support verbal communication in children (Grassmann & Tomasello, 2010), and promote content specific learning (Singer & Goldin-Meadow, 2005). Gestures also play an equally important role in collaborative exercises, as students jointly embody movements to facilitate multimodal reasoning (Arzarello et al., 2009). Actively incorporating gestures into the learning environment not only supports learning but multiplies the avenues through which students can express themselves.

The development of technology for this project was inspired by research in the areas of digital-physical musical instrument design, participatory and ensemble sense making (De Jaegher & Di Paolo, 2007), STEAM education (Kritsis et al., 2018), and play (Tomas, 2020; Ikawa & Matsura, 2020; Barbosa et al., 2017). We draw on recent teaching and research (Barua et al., 2020; Mechtley et al., 2019; Sha, 2016; Synthesis, 2021; Thorn et al., 2020; Thorn et al., 2019) to create a digital-physical system for telematic musical making in ensemble that centers gesture and embodied interaction, which we call telematic embodied learning (TEL).

Furthermore, this study situates neurodiversity in the context of CT. Wing (2006) describes computational thinking (CT) as a process for "solving problems, designing systems, and understanding human behavior, by drawing on the concepts fundamental to computer science" (p. 33). The central task of CT is the formulation of problems that can be solved through computational steps (Aho, 2012). Furthermore, researchers credit CT in education with creating stronger ties to real-world contexts (Jona et al., 2014), with improving higher order thinking and collaborative problem-solving skills (Fessakis et al., 2013; Kafai & Burke, 2014) while it is also argued that CT can be inaccessible to individuals with disabilities (Burgstahler &

Ladner, 2006; Ladner & Stefik, 2017). Finally, education, in the context of CT, tends to reproduce learning modes that privilege linear, isolated, neurotypical, and cognitivist thinking over that of creative, interdependent, and embodied interaction.

Participants and methods

Four teacher fellows (TFs) with diverse professional backgrounds in fields including biomedical engineering, educational technology, early childhood, music, and fine arts were recruited to participate in the first part of this study. Teachers' areas of teaching entail STEAM, including math, science, and coding, adapted physical education (APE), and music/band in Title 1 schools. Two TFs exclusively serve students with autism; the others serve students with and without autism labels.

During year one, TFs participated in four researcher facilitated workshops held on Saturdays, each lasting three to six hours. These workshops introduced TFs to the core wearable music instruments and created a space for dialogue, practice through play and experimentation, and instructional planning. Between each workshop, TFs used the technology themselves and with their students. Feedback from TFs to the researchers directed multiple iterations of the M5Stick device as well as the various instruments (apps).

TF workshop mini-interviews and embodied interviews comprised the data sources for this study. TF interviews included questions about their past, current and planned CT experiences and neurodiverse pedagogies. Mini-interviews were approximately five to ten minute open interviews held during workshops 2 through 4 with all TFs. Embodied semi-structured interviews (Kvale, 2015), in turn, asked participants to elaborate their responses while engaging in play and musical exploration and lasted up to 60 minutes. Embodied interview data included audio and photographs. Interview audio was transcribed and then critical incidents, events that had specific significance or that made a considerable contribution to the lives and experiences of the participants (Angelides, 2001; Flanagan, 1953; Tirri & Koro-Ljungberg, 2002), were identified. We defined critical events in this context as events with significance for TF development of neurodiverse pedagogies. These events were further described as either, (a) surprising or unexpected events indicated by the TF that caused them to think differently, (b) a moment mentioned by the TF where new pedagogical possibilities were considered, and (c) TF process/development of new or shifting pedagogical perspectives during the interview. Identified critical incidents were grouped, categorized, and searched for patterns across and within individuals.

Findings

Initial results from critical event analysis indicated that teachers experienced critical events related to the development of neurodiverse pedagogies as issues of balance in structure and improvisation, multisensory and multimodal learning, engagement with purpose, and the valuing of nonstandard teaching/learning methods. For example, neurodiverse pedagogies involved a delicate balancing of structure and improvisation (Beghetto & Kaufman, 2011; Sawyer, 2019). It was felt that the technology in this project provided sufficient structure to guide CT learning that was not completely chaotic.

> “This allows you to have sufficient structure. There’s only certain movements that make sound. They’re not gonna just go crazy… It allows you to introduce topics of movement and music which could be chaotic, but it gives you enough structure with the technology. It ends up working out alright” (TF1).

TFs also felt that teaching neurodiverse students necessitated multiple pathways, rather than one direct path. Thus, teaching included multiple strategies and approaches. In addition, TFs continue to develop neurodiverse pedagogies that generate multisensory and multimodal learning in the context of CT. Activating the brain to process information using different sensory modes helps students make new or different connections (Arzarello et al., 2009; Barsalou, 2008).

> "Something I didn't really think about until we started playing around with these instruments is that my teaching has really been limited to sight. We write a code and you see it on the screen. Then it produces some output that the students see. Almost everything I do is visual, but to assume that every student is a visual learner wouldn't be an appropriate assumption to make…I didn't think about this but, yeah, learning should be using as many senses as possible. That's activating more areas in your brain. It's creating more connections because you're linking into all your senses" (TF2).

Furthermore, TFs realized that sensory modes are not separate from each other, so developing technology, apps, activities, and strategies that combine senses could help in a classroom with neurodiverse students (Manning & Massumi, 2014). Along with multisensory, multimodal teaching was described as using multiple lessons, low tech to high tech, multiple times throughout the year.

The TFs who teach STEM stressed engagement with purpose. They felt that the technology was initially highly engaging, but there needed to be meaningful and purposeful activities to keep students engaged. More specifically STEM teachers described that they began lesson planning with a CT concept in mind, then used the technology to teach, reteach or supplement the teaching of that concept, reminiscent of a spiral curriculum model (Ireland & Mouthaan, 2020). But overall, the end goal was to get the students to think deeply and apply their understanding; "I'm gonna push them into something a little bit higher so that they can get exposed to higher order thinking, creation. Then, hopefully that will build up overtime 'cause that doesn't happen overnight" (TF2).

TFs developed neurodiverse pedagogies because they valued the use of nonstandard teaching and learning methods for their students. TF2 described reciprocal teaching pedagogy where the teacher is the lead learner and stressed the multisensory and multimodal teaching strategies mentioned above. This TF also noticed how these pedagogies, along with the developing technology, were affecting social and emotional learning. TF2 also alluded to a difference in neurodiverse learning time when mentioning direct and nonlinear teaching structures (Ireland & Mouthaan, 2020). TF1 described how neurodiverse pedagogies include multiple pacings which can accommodate all students (Holmlund et al., 2018). Additionally, TF1 explained that teachers can be intentional about the kinds of CT activities they present so that diverse thinking styles are accepted, and even encouraged. For example, teachers could "give students a physical challenge where they're using kinesthetic learning and they're building something. This actually opens the door for students who have nonstandard ways of thinking about and processing information" (TF1).

TFs experienced neurodiverse pedagogies as structure and improvisation, multisensory, multimodal learning, purposeful engagement, and nonstandard teaching/learning methods. These experiences contributed to modification and diversification of CT teaching as related to the subject area, students, M5Stick device, and apps.

Scholarly Significance

The broader impact of this research addresses CT education and the need for more inclusive educational practices that will benefit all neurodiverse individuals and especially those with autism, their teachers, and ultimately employers of neurodiversity. We study and generate curricular materials and instructional technologies that teachers in middle and high schools can adapt for neurodiverse learners in the context of STEM and CT. Furthermore, this study specifically speaks to the teacher's experiences developing neurodiverse pedagogy, which encourages difference, offers supports and scaffolds, and presumes competence. This practical knowledge and insight into neurodiverse education, computer science, and creativity can lead to more stimulating teaching practices and educational materials, increased respect for neurodiverse children in schools, and pathways of support and facilitation that increase the employment potential of neurodiverse students, including those with autism, in a more inclusive economy.

References

Aho, A. V. (2012). Computation and Computational Thinking. *Computer Journal*, *55*(7), 832–835.

Angelides, P. (2001). The development of an efficient technique for collecting and analyzing qualitative data: the analysis of critical incidents. *International Journal of Qualitative Studies in Education*, *14*(3), 429-442.

Arzarello, F., Paola, D., Robutti, O., & Sabena, C. (2009). Gestures as semiotic resources in the mathematics classroom. *Educational Studies in Mathematics*, *70*(2), 97–109.

Barbosa, J., Wanderley, M. M., & Huot, S. (2017). Exploring Playfulness in NIME Design: The Case of Live Looping Tools. *Proceedings of the International Conference on New Interfaces for Musical Expression*, 87–92. https://doi.org/10.5281/zenodo.1176181

Barsalou, L. W. (2008). Grounded cognition. *Annual Review of Psychology*, *59*, 617–645.

Barua, S., Lyu, Y., Rawls, C., Weisman, P., Spackman, C., & Sha, X.W. (2020). *Connectivity Café: Prototyping the Dining Event.* ISEA 2020.

Beghetto, R. A., & Kaufman, J. C. (2011). Teaching for creativity with disciplined improvisation. In R. K. Sawyer (Ed.), *Structure and improvisation in creative teaching* (pp. 94-109). Cambridge University Press.

Bhambra, G. K., Gebrial, D., & Nisancioglu, K. (2018). *Decolonizing the University.* Pluto Press.

Bhambra, G. K., Nisancioglu, K., & Gebrial, D. (2020). Decolonizing the University in 2020 *Identities: Global Studies in Culture and Power,* 27(4), 509-516.

Burgstahler, S., & Ladner, R. (2006). An alliance to increase the participation of individuals with disabilities in computing careers. *ACM SIGACCESS Accessibility and Computing*, 85, 3–9. https://doi.org/10.1145/1166118.1166119

de Sousa Santos, B. (2015). *Decolonizing the University: The Challenge of Deep Cognitive Justice.* Cambridge University Press.

De Jaegher H., and Di Paolo E (2007). Participatory Sense-Making: An enactive approach to social cognition. *Phenomenology and the Cognitive Sciences*, 6(4), 485-507.

Fessakis, G., Gouli, E., & Mavroudi, E. (2013). Problem solving by 5–6 years old kindergarten children in a computer programming environment: A case study. *Computers & Education*, *63*, 87–97.

Flanagan, J. (1953). *The critical incident method.* Pittsburgh, PA: American Institute for Research and University of Pittsburgh.

Fyfe, E. R., McNeil, N. M., Son, J. Y., & Goldstone, R. L. (2014). Concreteness fading in mathematics and science instruction: A systematic review. *Educ. Psychol. Rev. 26*, 9–25. doi: 10.1007/s10648-014-9249-3

Grassmann, S., & Tomasello, M. (2010). Young children follow pointing over words in interpreting acts of reference. *Developmental Science, 13*(1), 252-263.

Holmlund, T. D., Lesseig, K., and Slavit, D. (2018). Making sense of "STEM education" in K-12 contexts. *International Journal of STEM Education, 5*(32), 1-18.

Ikawa, Y., & Matsuura, A. (2020). Playful audio-visual interaction with Spheroids. In R. Michon & F. Schroeder (Eds.), *Proceedings of the International Conference on New Interfaces for Musical Expression* (pp. 188–189). Birmingham City University. https://www.nime.org/proceedings/2020/nime2020_paper36.pdf

Ireland, J., and Mouthaan, M. (2020). Perspectives on curriculum design: Comparing the spirla and the network models. *Research Matters, 30,* 7-12. University of Cambridge Local Examination Syndicate.

Jona, K., Wilensky, U., Trouille, L., Horn, M. S., Orton, K., Weintrop, D., & Beheshti, E. (2014). *Embedding computational thinking in science, technology, engineering, and math (CT-STEM).* Future Directions in Computer Science Education Summit Meeting, Orlando, FL. http://ccl.sesp.northwestern.edu/papers/2014/OrtonKaiNorthwestern-1.pdf

Kafai, Y. B., & Burke, Q. (2014). *Connected Code: Why Children Need to Learn Programming*. MIT Press.

Kritsis, K., Gkiokas, A., Acosta, C. Á., Lamerand, Q., Piéchaud, R., Kaliakatsos-Papakostas, M., & Katsouros, V. (2018). A web-based 3D environment for gestural interaction with virtual music instruments as a STEAM education tool. In T. M. Luke Dahl Douglas

Bowman (Ed.), *Proceedings of the International Conference on New Interfaces for Musical Expression* (pp. 348–349). Virginia Tech. https://doi.org/10.5281/zenodo.1302613

Kvale, S. (2015). *InterViews: Learning the craft of qualitative research interviewing* (3rd Ed.). SAGE.

Ladner, R. E., & Stefik, A. (2017). AccessCSforall: making computer science accessible to K-12 students in the United States. *SIGACCESS Access. Comput.*, *118*, 3–8.

Liao, C. (2016). From interdisciplinary to transdisciplinary: An arts-integrated approach to STEAM education. *Art Education*, *69*(6), 44-49.

Manning, E., & Massumi, B. (2014). *Thought in the act: Passages in the ecology of experience.* University of Minnesota Press.

Mechtley, B., Ingalls, T., Stein,J., Rawls, C., Sha, X.W. (2019). SC: A modular software suite for composing continuously-evolving responsive environments. In (Eds.) P. Beesley, S. Hastings, & S. Bonnemaison, *Living Architecture Systems Group White Papers*. Riverside Architectural Press.

Page, M. (1990). *Active learning: Historical and contemporary perspectives*. [Unpublished doctoral dissertation]. University of Massachusetts.

Paperson, L. (2017). *A Third University is Possible.* University of Minnesota Press.

Pugh, J., & Grove, K. (2017). Assemblage, transversality and participation in the neoliberal university, *Environment and Planning D: Society and Space,* 35(6), 1134-1152.

Roux, A. M., Shattuck, P. T., Rast, J. E., Rava, J. A., & Anderson, K. A. (2015). *National Autism Indicators Report: Transition into Young Adulthood*. Life Course Outcomes Research Program, A.J. Drexel Autism Institute, Drexel University.

Sawyer, K. (2019). *The creative classroom: Innovative teaching for 21st-century learners*. Teachers College Press.

Sha, X.W. (2016). Theater Without Organs: Co-articulating gesture and substrate in responsive environments. In P. Beesley & A. Roushan (Eds.), *Living Architecture Systems Group White Papers,* (pp. 276–291). Riverside Press.

Shattuck, P. T., Narendorf, S. C., Cooper, B., Sterzing, P. R., Wagner, M., & Taylor, J. L. (2012). Postsecondary education and employment among youth with an autism spectrum disorder. *Pediatrics*, *129*(6), 1042-1049.

Silberman, S. (2016). *NeuroTribes: The legacy of autism and the future of neurodiversity.* New York, NY: Avery.

Singer, M. A., & Goldin-Meadow, S. (2005). Children learn when their teacher's gestures and speech differ. *Psychological Science, 16*(2), 85–89.

Synthesis (2021). *Synthesis Center for Transversal Research*. Arizona State University. Online: http://synthesiscenter.net .

Thorn, S., Willcox, H., Sha, X. W. (2020). *Processual and experiential design in wearable music workshopping.* In Proceedings of the 7th International Conference on Movement and Computing. Association for Computing Machinery. https://doi.org/10.1145/3401956.3404235.

Thorn, S. D., & Wei, S. X. (2019). Instruments of Articulation: Signal Processing in Live Performance. *Proceedings of the 6th International Conference on Movement and Computing*. https://doi.org/10.1145/3347122.3347133

Tirri, K. & Koro-Ljungberg, M. (2002). Tirri, K. & Koro-Ljungberg, M. (2002). Critical incidents in the lives of gifted female Finnish scientists. *The Journal of Secondary Gifted Education, 13(*4), 151-163.

Tomás, E. (2020). A playful approach to teaching NIME: Pedagogical methods from a practice-based perspective. In R. Michon & F. Schroeder (Eds.), *Proceedings of the International Conference on New Interfaces for Musical Expression* (pp. 143–148). Birmingham City University. https://www.nime.org/proceedings/2020/nime2020_paper28.pdf

Walker, N. (n.d.). *Neurodiversity: Terms and definitions.* Neuroqueer. https://neuroqueer.com/neurodiversity-terms-and-definitions/

Wing, J. M. (2006). Computational thinking. *Communications of the ACM*, *49*(3), 33–35.