Redesigning EarSketch for Inclusive CS Education: A Participatory Design Approach

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ABSTRACT

This study conducts a novel approach to redesign EarSketch, an expressive computer science (CS) learning environment that integrates music composition into computing education, with a specific focus on inclusivity for blind and visually impaired (BVI) learners. This approach centers on the participation of teachers, students, and the community as co-designers, leveraging their insights and experiences to enhance the program's accessibility and effectiveness. By actively involving the stakeholders in the development process, the study aims to address the unique educational challenges and needs of learners who are visually impaired more effectively. The participatory design approach is expected to not only maintain the intrinsic appeal of EarSketch but also to expand its accessibility, ensuring that it becomes a more inclusive tool in computer science education. The ultimate goal is to establish a more adaptable and inclusive educational paradigm within STEAM, particularly in computing education and music, that is responsive to the diverse needs of all students, including those with visual impairments. The contributions of this paper are design recommendations based on our data that can be applied to the design of EarSketch and other expressive CS environments for BVI learners.

CCS CONCEPTS

• Human-centered computing → Accessibility; **• Applied computing → Interactive learning environments**; **Sound and music computing**;

KEYWORDS

EarSketch, Participatory Design, Educational Technology, STEAM, Accessible Computing

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1 INTRODUCTION

Integrating music composition and computer science (CS) education has engaged students in innovative ways. Music in particular has the opportunity to engage learners who are blind and visually impaired (BVI) who may be otherwise disenfranchised by other popular methods of engagement in CS education that rely heavily on visual tasks such as drawing, animation, or game development [1, 13]. This paper explores the importance of inclusive design practices in CS education, conducts a participatory approach to the inclusive redesign of musical computing environments for learners who are BVI to inform inclusive practices in music-based CS education platforms, and reports on the initial findings from this approach used in observation and teacher interviews.

However, there is a need to engage teaching methods in computer science education and inclusive designs for diverse learners, including those with visual impairments. Past work has discussed the challenges and necessities of making computing education accessible to students who are visually impaired [6, 9, 11]. Ludi [7] identifies several key difficulties including inadequate screen reader skills, navigation issues, ineffective feedback from tools, and a lack of accessible learning materials. These works advocate for improvements in accessibility, suitable development tools, and the use of co-design to create user-centered, inclusive learning environments.

EarSketch is an online learning environment in which learners use Python or JavaScript code to manipulate sound samples and create music [8]. Its novel approach of merging sample-based music creation with computing has been found to enhance student engagement [4] and introduce creative ways to tackle computing challenges like auto-grading programs for both technical and creative merit [12, 14], a recommendation system for samples based on user behavior and audio analysis [15, 17, 18], and real-time assistance with coding and music production [16, 19]. EarSketch significantly improves student engagement and persistence in computing through its integration of music and programming languages [3, 20]. Additionally, EarSketch's role in fostering a sense of identity and belonging in computing among students is crucial in sustaining interest and participation in STEM fields [10]. EarSketch, which relies on a visually focused user interface with multiple panels and

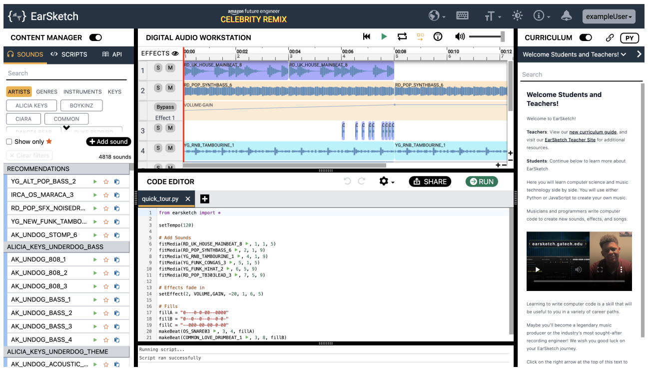

Figure 1: The interface of the EarSketch web application, with Content Browser (left), Digital Audio Workstation (top), Code Editor (bottom), and Curriculum (right).

textual curriculum chapters (Figure 1), requires design changes to become more accessible to users who are blind or visually impaired.

Previous research gives some guidance for designing a more inclusive EarSketch, often discussing the crucial role of using innovative tools and methodologies. Co-design where users are actively involved in the design process leads to more user-centered outcomes and helps designers better understand users' needs and contexts [9]. This approach is particularly beneficial in creating more accessible and inclusive technologies for people with disabilities. Additionally, teachers in computer science education require ongoing professional development to adapt to new technological pedagogies [2], positioning them as key stakeholders in the process of adapting learning environments to meet student needs. This prior work makes a compelling case for a redesign of EarSketch focusing on inclusivity, engagement, and the integration of creative and accessible teaching approaches.

Informed by the prior work above and our pilot research [5], we hypothesize that *music programming learning environments, like EarSketch, can be re-designed for and with students who are BVI to educate learners who are BVI in computer science and improve their attitudes towards computing as a discipline.* More specifically, we hypothesize that a more accessible version of EarSketch (*EarSketch v3*)—designed with and for students who are BVI—will lead to gains similar to those sighted students have enjoyed in EarSketch: content knowledge gain in students who are BVI (as measured by code complexity and pre/post content knowledge assessments), interest formation, belongingness, and intent to persist in computing (as measured via pre/post surveys). In addition, we hypothesize that the code complexity, positive attitudinal changes, and evidence of engagement we see amongst students who are BVI will be comparable to changes we see in data from current and former sighted student users of EarSketch.

2 RESEARCH QUESTIONS

At the center of this redesign lies a critical inquiry: *How can EarSketch be redesigned better to empower users in their musical and computational exploration while ensuring inclusivity, accessibility, and relevance across diverse educational contexts?* To address the question comprehensively, the methodology integrates a multifaceted approach, combining qualitative and quantitative research methods with universal design principles and iterative development cycles. We aim to answer the following research questions:

2.1 RQ1 (Human Studies): What elements of a learning environment afford music programming and computing education for learners including those who are blind or visually impaired?

To answer this research question, we aim to gather and understand information about how learners who are BVI interact with educational and creative technology.

Objective 1: To expand our understanding of the preferences of students who are BVI and their needs for computing education and music programming environments, we will conduct focus group interviews with students who are BVI and their parents and teachers as well as iterative participatory design sessions.

Objective 2: To identify authentic practices used and challenges faced by both music programmers and software developers who are BVI, we will conduct a literature review and interviews with developers and music programmers who are BVI.

Objective 3: To identify best practices, including screen reader support and additional approaches that make use of auditory cues for a) system navigation, b) code presentation/editing, and c) music composition in Digital Audio Workstation (DAW) interfaces, we will manage literature review, iterative design of prototypes, user focus groups, and consultation with software developers and teachers.

Objective 4: To identify best practices for curricular design for computer science learning for students who are BVI, we will conduct a literature review, interviews with teachers, iterative design, and trial use with teachers.

2.2 RQ2 (Building Systems): How can we design music+CS learning platforms to better support the learning and creativity of students including those who are blind or visually impaired?

This research question will guide how we build new systems or redesign EarSketch to meet the needs of students who are BVI based on the information gathered in our studies.

Objective 1: To adopt best practices for music programming, software development, navigation using auditory cues, and curricular design identified in RQ1 to EarSketch, we will execute iterative prototyping and design, participatory design with relevant stakeholders, and user studies with teachers and students who are BVI as well as parents.

Objective 2: We aim to lead professional development (PD) workshops for teachers to help them use *EarSketch v3* with students who are BVI, teach students who are BVI with *EarSketch v3*. The teacher's workshop will use an updated EarSketch PD materials and implementation guide. We will also evaluate positive teacher reactions to professional learning on teacher surveys.

2.3 RQ3 (Evaluation): Does learning how to program in an accessible music+CS learning environment like *EarSketch V3* foster content knowledge gain, interest development, feelings of belonging, and intent to persist in CS amongst students including those who are blind or visually impaired?

To answer this research question, we will assess the effects of our redesign platform on students who are BVI.

Objective 1: We will assess whether *EarSketch v3* fosters learning in CS for students who are blind or visually impaired. Pre and post-content knowledge assessments, analysis of student interaction logs, and interviews with students and teachers will be used as methods. We will also implement *EarSketch v3* in classrooms with students who are BVI to determine student success through student artifacts.

Objective 2: To assess whether *EarSketch v3* fosters engagement and intent to persist in computing for students who are blind or visually impaired, we will conduct surveys.

Objective 3: To assess whether *EarSketch v3* fosters comparable learning engagement for students who are BVI, we will use comparative analysis of code complexity, interest to persist in CS between students who are BVI and students who are sighted. The measurable outcomes include artifacts demonstrating student success, such as completed projects and assessments, along with evidence supporting the hypothesis regarding learner engagement, attitude, and intent to persist in computer science education.

3 METHODOLOGY

The ongoing study was structured around qualitative methods to capture deep insights into the instructional dynamics within BVI students' classrooms. Our current research study design included two main phases: direct classroom observations at the California School for the Blind (CSB) during its Day of Code learning event[1] and subsequent structured interviews with the teachers involved.

3.1 Data Collection

3.1.1 Classroom Observation. Observations were methodically planned with a focused observation log, focusing on four key areas to gather comprehensive data. This approach was aimed at meeting the real needs of the classroom and addressing educational challenges identified during the observations, ensuring that the design actions developed were both meaningful and effective.

(1) *Teacher's Moves and Pedagogical Practices.* We documented the instructional strategies and classroom management techniques used by teachers, providing insights into existing pedagogical approaches.
(2) *Implications for Teacher Co-design Sessions.* We observed teacher behaviors to refine and develop our subsequent stages of teacher co-design sessions.
(3) *Implications for Student Co-design Sessions.* We assessed student interactions, engagement, and preferences to advance student co-design sessions effectively.
(4) *Implications for EarSketch System Design.* We focused on observing students' use of technology and interfaces for coding in the classroom to inform the redesign of EarSketch.

3.1.2 Teacher Interviews. Following the observation phase, we conducted structured interviews with four teachers (one male and three females, including one teacher who is visually impaired) from the California School for the Blind. These interviews were designed to gather in-depth information about the teachers' professional backgrounds, the technologies they use, their pedagogical strategies, and the challenges they encounter in educating BVI students. We divided our questions into four categories: (1) Teacher background and experience, (2) The use and effectiveness of assistive technologies during the event, (3) The challenges and instructional strategies differentiated by educational level, and (4) Classroom dynamics and audio management.

3.2 Data Analysis

The Data collected from both observation and interviews were transcribed and analyzed using thematic analysis with a collaborative coding process. This methodology provided a comprehensive understanding of the educational dynamics within BVI-targeted settings to facilitate the development of upgraded educational tools and strategies, offering valuable insights for our research targeting BVI learners in an authentic CS learning environment.

4 INITIAL RESULTS

The initial stage of our research involved participants from both low and high-domain backgrounds. Firstly, observations at the Day of Code event offered firsthand perspectives on classroom dynamics and instructional techniques related to EarSketch (RQ1). These initial findings establish a strong foundation for further exploration and refinement in the ongoing redesign process of EarSketch (RQ2). We also had discussions with four teachers at the event and performed extended interviews with them over Zoom video calls throughout December 2023. The interviews lasted one hour on average and participants were compensated with $150 USD gift cards.

4.1 Classroom Observations

Our classroom observations provided unique insights into the implementation of EarSketch in authentic educational contexts. Children who participated in this research were students enrolled in the CSB Day of Code event. Observers highlighted the usability issues of the interaction between learners and screens, the observable engagement levels of the learners, and the potential impact of instructional approaches for EarSketch.

The initial observations highlighted the importance of addressing visibility issues, keyboard navigation, and syntax errors within the EarSketch platform. For example, researchers observed how ZoomText screen magnification[2] can impede a student's ability to find things on the right side of the screen, with one student turning

[1] https://csb-cde.ca.gov/about/events/dayofcode.aspx

[2] https://www.freedomscientific.com/products/software/zoomtext/

off ZoomText to locate what they were looking for. Additionally, it was observed how many syntax errors were the result of misspelled words, indicating a need for typing assistance or feedback in EarSketch.

Other insights include implementing accessible feedback channels from diverse stakeholders like teachers, students, and communities recognizing diverse hardware such as touchscreen computers, and prioritizing keyboard-centric navigation. In particular, teachers are encouraged to use arrow keys and shift instead of relying on mouse navigation. Researchers also observed the effectiveness of unique and informative directional commands from teachers such as " Come toward my voice" and "Move to the right of my voice" when assisting students in navigating the classroom, especially when combined with tactile and audio feedback in the tools used by students.

Other essential classroom management strategies included clear statements for seeking help, like "If you need help, clap and I will come over." Teachers further enrich learning dynamics by providing other detailed oral directions, sometimes paired with physical artifacts provided to students. For instance, one teacher explained to their student how "the 'start' has a square to the left and 'stop' has a triangle to the right." Scaffolding techniques are shared to resolve technological challenges for students to tackle obstacles independently over time, with teacher advice such as "How do you find the mouse?" "'Corner it'; put it in the top right corner - then find it." These observations contribute to a comprehensive understanding of the user experience and present actionable insights to guide redesign efforts for a more effective and inclusive EarSketch in classroom settings.

4.2 Teacher Interviews

The interviews with the four teachers at the CSB revealed crucial aspects of the EarSketch platform's effectiveness and usability in diverse educational settings. The feedback emphasized the need for clearer instructional strategies, detailed guidance, and scaffolding techniques tailored to learners of varying ages and abilities. Additionally, insights on minimizing reliance on the mouse in favor of keyboard navigation were highlighted. Observations on classroom management strategies and student orientation within the digital space played a pivotal role in shaping redesign efforts, emphasizing inclusivity and user-friendliness.

Subjects revealed the challenges faced by learners who are BVI, particularly children, in navigating technology. Learning curves for ubiquitous technology in daily life can be steep for individuals who are BVI. To bridge the gap, it is necessary to design an accessible interface with the user's experience in mind, prioritizing ease of use, clarity, and effective organization. As one teacher stated, "Things need to be streamlined and made in a way that makes sense. So, things should be labeled well, have sections that make sense, and be easy to navigate. If they are going to include visual aspects, I think those visual aspects shouldn't be the main focus." They added, "I think that I can consistently do better with the coding of the web pages to make them even easier to follow and navigate."

Additionally, comprehensive instructional strategies, effective direct teaching methods, and differentiation are necessary to bridge the gap created by parents' unfamiliarity with assistive technology. As one teacher stated, "People don't have the same community of access. Their parents don't know how to use a screen reader, so there's a lot of different checklists, a lot of like direct teaching in getting kids up to speed with using technology and we try to start really young." Another teacher also emphasized the importance of offering scaffolding assistance during coding sessions to provide the necessary personalized guidance for students.

5 LIMITATIONS & CONCLUSIONS

The study's limitations include a small sample of four teachers from the California School of Blind (CSB), which may not fully represent diverse educational settings or perspectives. Additionally, the observations conducted by only three researchers during a single "Day of Code" were limited in duration, potentially restricting the depth of insights into classroom dynamics and long-term teachers and student behavior. Our observation of students in a dedicated School for the Blind also limits the scope of our findings to the experiences of students in classrooms designed to accommodate them. Furthermore, the design recommendations derived from these observations have yet to be empirically tested with learners who are Blind and Visually Impaired (BVI), leaving their practical effectiveness for expressive CS learning environments to be verified in future research.

In conclusion, based on our findings from our initial research with teachers and students at the California School for the Blind, the redesign of *EarSketch v3* presents an opportunity to advance inclusive CS education. By embracing participatory design principles and prioritizing accessibility, we aim to create a platform that meets the diverse needs of learners by prioritizing enhancements in three main areas. Firstly, *the user interface should be redesigned to feature simplified navigation and clearer labeling for scaffolding, ensuring ease of use for learners.* Introducing personalized features can further enhance the user experience, allowing learners to tailor the interface to their preferences. Secondly, *accessible integration is essential for inclusivity, and this can be achieved through authentic representation and the incorporation of descriptive audio cues.* Additionally, providing tactile feedback for learners who are BVI to interact with music compositions programmatically can greatly benefit those with diverse learning needs. Lastly, *incorporating real-time and long-term user feedback mechanisms, including the integration of teachers, students, and related parties' feedback mechanisms, is crucial for ongoing improvement.* These lessons apply both to the development of a more accessible EarSketch and its integration with lessons for students who are BVI. This iterative process of gathering and implementing feedback will ensure that the learning platform evolves to meet the changing needs of its users.

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REFERENCES

[1] Matthew Conway, Steve Audia, Tommy Burnette, Dennis Cosgrove, and Kevin Christiansen. 2000. Alice: lessons learned from building a 3D system for novices. In *Proceedings of the SIGCHI conference on Human factors in computing systems*. 486–493.

[2] Werner Engelbrecht and Piet Ankiewicz. 2016. Criteria for continuing professional development of technology teachers' professional knowledge: A theoretical perspective. *International Journal of Technology and Design Education* 26 (2016), 259–284.

[3] Shelly Engelman, Brian Magerko, Tom McKlin, Morgan Miller, Doug Edwards, and Jason Freeman. 2017. Creativity in authentic STEAM education with EarSketch. In *Proceedings of the 2017 ACM SIGCSE Technical Symposium on Computer Science Education*. 183–188.

[4] Jason Freeman, Brian Magerko, Doug Edwards, Tom Mcklin, Taneisha Lee, and Roxanne Moore. 2019. EarSketch: engaging broad populations in computing through music. *Commun. ACM* 62, 9 (2019), 78–85.

[5] Stephen Garrett, Jason B Smith, Amber Blue, Zerrin Ondin, Johan Rempel, Kara Mumma, Jason Freeman, and Brian Magerko. 2024. Improving the Accessibility of the EarSketch Web-Based Audio Application for Blind and Visually Impaired Learners. In *Proceedings of the International Web Audio Conference* (West Lafayette, Indiana, USA, 2024-03) *(WAC '24)*.

[6] Earl W Huff Jr, Kwajo Boateng, Makayla Moster, Paige Rodeghero, and Julian Brinkley. 2021. Exploring the perspectives of teachers of the visually impaired regarding accessible k12 computing education. In *Proceedings of the 52nd acm technical symposium on computer science education*. 156–162.

[7] Stephanie Ludi. 2014. Robotics programming tools for blind students. *Journal on Technology and Persons with Disabilities* 1 (2014), 81–91.

[8] Brian Magerko, Jason Freeman, Tom Mcklin, Mike Reilly, Elise Livingston, Scott Mccoid, and Andrea Crews-Brown. 2016. Earsketch: A steam-based approach for underrepresented populations in high school computer science education. *ACM Transactions on Computing Education (TOCE)* 16, 4 (2016), 1–25.

[9] Charlotte Magnusson, Per-Olof Hedvall, and Héctor Caltenco. 2018. Co-designing together with Persons with Visual Impairments. *Mobility of visually impaired people: fundamentals and ICT Assistive Technologies* (2018), 411–434.

[10] Tom McKlin, Brian Magerko, Taneisha Lee, Dana Wanzer, Doug Edwards, and Jason Freeman. 2018. Authenticity and personal creativity: How EarSketch affects student persistence. In *Proceedings of the 49th ACM Technical Symposium on Computer Science Education*. 987–992.

[11] Aboubakar Mountapmbeme and Stephanie Ludi. 2020. Investigating challenges faced by learners with visual impairments using block-based programming/hybrid environments. In *Proceedings of the 22nd International ACM SIGACCESS Conference on Computers and Accessibility*. 1–4.

[12] Seyedahmad Rahimi, Jason Brent Smith, Erin JK Truesdell, Ashvala Vinay, Kristy Elizabeth Boyer, Brian Magerko, Jason Freeman, and Tom Mcklin. 2023. Validity and Fairness of an Automated Assessment of Creativity in Computational Music Remixing. In *Proceedings of the Workshop on Automated Assessment and Guidance of Project Work co-located with 24th International Conference on Artificial Intelligence in Education*.

[13] Mitchel Resnick, John Maloney, Andrés Monroy-Hernández, Natalie Rusk, Evelyn Eastmond, Karen Brennan, Amon Millner, Eric Rosenbaum, Jay Silver, Brian Silverman, et al. 2009. Scratch: programming for all. *Commun. ACM* 52, 11 (2009), 60–67.

[14] Avneesh Sarwate, Creston Brunch, Jason Freeman, and Sebastian Siva. 2018. Grading at scale in earsketch. In *Proceedings of the Fifth Annual ACM Conference on Learning at Scale*. 1–4.

[15] Jason Smith, Mikhail Jacob, Jason Freeman, Brian Magerko, and Tom Mcklin. 2019. Combining collaborative and content filtering in a recommendation system for a web-based daw. In *Proceedings of the International Web Audio Conference*.

[16] Jason Smith, Erin JK Truesdell, Jason Freeman, Brian Magerko, Kristy Elizabeth Boyer, and Tom McKlin. 2020. Modeling music and code knowledge to support a co-creative ai agent for education. In *Proceedings of the 20th International Society for Music Information Retrieval Conference*. 134–141.

[17] Jason Smith, Dillon Weeks, Mikhail Jacob, Jason Freeman, and Brian Magerko. 2019. Towards a hybrid recommendation system for a sound library. In *Joint Proceedings of the ACM IUI Workshops*.

[18] Jason Brent Smith, Ashvala Vinay, and Jason Freeman. 2023. The Impact of Salient Musical Features in a Hybrid Recommendation System for a Sound Library. In *Joint Proceedings of the ACM IUI Workshops*.

[19] EJ Truesdell, Jason Brent Smith, Sarah Mathew, Gloria Ashiya Katuka, Amanda Griffith, Tom McKlin, Brian Magerko, Jason Freeman, and Kristy Elizabeth Boyer. 2021. Supporting Computational Music Remixing with a Co-Creative Learning Companion. In *Proceedings of the Twelfth International Conference on Computational Creativity*.

[20] Dana Linnell Wanzer, Tom McKlin, Jason Freeman, Brian Magerko, and Taneisha Lee. 2020. Promoting intentions to persist in computing: an examination of six years of the EarSketch program. *Computer Science Education* 30, 4 (2020), 394–419.

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