Using Co-Design to Investigate Affordances of an Expressive CS Learning Environment for Students who are BVI

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Abstract

Expressive computer science (CS) learning environments teach coding through the creation of an artifact, such as audio or video output. EarSketch is an expressive CS learning environment designed to teach computing through music production, mixing and arranging sounds using code. In this paper, we explore the accessibility challenges of using EarSketch for learners who are Blind and Visually Impaired (BVI). We present key findings from co-design studies with teachers and students at an institution specializing in BVI education, focused on gathering both groups' unique perspectives about EarSketch's ability to support teachers' curricula, students' workflows using the system with accessibility software, and challenges faced by users who are BVI.

CCS Concepts

• Applied computing → Interactive learning environments; **Sound and music computing**; **• Human-centered computing → Accessibility design and evaluation methods**; **• Social and professional topics → People with disabilities**.

Keywords

Accessible Computing, Co-Design, Educational Technology

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1 Introduction

Expressive computer science (CS) learning environments enable learners to engage in creative tasks using code, building skills in computational thinking, problem solving, and self-expression. They are popular for engaging high schoolers in coding through the creation of creative artifacts, such as visual or musical art [11, 12, 28]. However, many of these platforms are heavily visually focused and inaccessible to learners who are blind and visually impaired (BVI). This paper explores how accessibility in expressive CS environments for learners who are BVI can be assessed and improved through both learner and educator input, using the EarSketch [19] online learning environment as a case study.

EarSketch (see Appendix Figure 1) teaches coding through sample-based music composition [19]. It has had over 1.5 million users and gained popularity for its web-based interface, which was designed to represent key features of authentic music production environments and software development tools [9, 12]. As the artifacts created using EarSketch are highly audible, it is well-positioned to support BVI-accessible computing education; however, its interface was not originally designed to accommodate learners who are BVI. This work aims to address this limitation by adapting EarSketch to better support BVI inclusivity by including learners who are BVI and their educators in co-design [33].

We partnered with an institution specializing in education for students who are BVI. We took a dual approach: (1) conducting interviews and a co-design workshop with teachers from this organization to identify preliminary ideas and best practices for designing music and CS learning platforms; then (2) conducting a co-design study with students from the same institution to identify their unique challenges and workflows.

In this paper, we present our methodology and findings from the co-design sessions and outline themes that have emerged from the qualitative analysis of teacher interviews and student feedback for the redesign of EarSketch as an accessible CS learning platform, which could inform the accessible design of other expressive CS learning platforms.

2 Related Work

Expressive CS learning environments apply constructionist learning theories centered on the creation of artifacts to build knowledge [10] in CS classrooms through guided activities [3, 8] that support and scaffold lessons to teach computer skills that support the learner's personal agency [4, 35]. EarSketch, which has enabled and motivated K-12 students[1] with its expressive and authentic music production environment, has the opportunity to provide learners who are BVI with an environment that supports a large range of creative activities they can perform independently [9, 21]. Considering learners' needs is critical to making CS learning environments accessible to as many learners as possible.

Existing approaches to make coding environments more accessible include compliance with screen reader labels [31], increasing color contrasts and text sizes [25], and supporting keyboard navigation as implemented in Visual Studio Code[2]. However, these interventions are insufficient for expressive CS learning environments like EarSketch: Despite the addition of screen reader support, elements and workflows designed by sighted developers for sighted users did not fully represent the needs of users who are BVI [13]. Co-design with learners who are BVI is necessary to learn and accommodate for their unique workflows with expressive CS learning environments [6, 7]. Our approach of collecting information from K-12 students and teachers with disabilities through activities and group discussions to create effective solutions is based on previous co-design with students who are visually impaired in K-12 classrooms [20, 22, 26] as well as software and educational materials to support blind audio producers [29, 30].

3 Teacher Co-Design

In May 2024, we performed interviews and co-design activities with teachers at a K-12 school for students who are BVI. EarSketch contains a curriculum of coding and music concepts, but typically relies on teachers to facilitate instruction in their classroom. The teacher's role in facilitating learning with EarSketch is especially apparent in a classroom for learners who are BVI because they provide hands-on, differentiated support [24] with high teacher-to-student ratios. Teachers are primary users of EarSketch alongside their students, interacting with it daily as they integrate it into their instructional practice. The primary goal of this study was to understand how teachers who work with learners who are BVI evaluate and adapt EarSketch for use in classrooms. Specifically, we sought insights on their experiences supporting these learners with EarSketch, focusing on both pedagogical observations (e.g., challenges their students encounter) and the teachers' own perspectives on the platform's usability, accessibility, and instructional affordances.

3.1 Study Design

The five participants were all teachers at a single institution specializing in BVI education. We selected participants with a variety of relevant experience (see Appendix Table 1): one female Curriculum Specialist, two female and one male Assistive Technology Specialists, and one female Teacher of the Visually Impaired. One participant had a visual impairment, and another was fully blind. None of the teachers had previously used EarSketch in their classes.

Appendix Table 2 describes the schedule and objectives of the teacher co-design study. After an online onboarding session, participants produced 15-second songs using functions from the EarSketch API to add sounds and effects. In online interviews, participants shared their experiences of integrating technology into their classrooms and their thoughts on EarSketch, as well as other expressive CS learning environments, regarding accessibility.

In an in-person co-design session, we asked participants to describe their experience with EarSketch using the Think-Pair-Share method [16]. Participants also discussed adapting EarSketch materials for their BVI-focused lesson plans. We then performed a User Needs Analysis [17], in which the teachers acted as students using EarSketch, to learn their perspectives on how students might adapt to using it. Our final discussion centered on how professional development for teachers of students who are BVI can support the adoption of new CS learning platforms.

We adopted a combined inductive-deductive qualitative analysis approach [34]. First, a team of six researchers (including the authors) familiarized themselves with the interview transcripts and co-design artifacts recorded during the study. We then collectively reviewed the full data corpus, incorporating codes derived from existing literature on expressive CS learning environments and the educational challenges reported by participants. We discussed code groupings and definitions as a team to create an initial codebook [5], resolving differences through iterative discussion. We then performed an inductive thematic analysis [2, 27] to identify a series of themes based on the codes through multiple iterative reviews.

3.2 Teacher Co-Design Findings

We identified two themes relating to supporting the use of EarSketch in teachers' pedagogy: (1) the differentiated support they provide to teach screen reader navigation and (2) how they scaffold material to support learner independence.

3.2.1 Differentiated Support for Screen Reader Navigation. Interviewees emphasized the importance of differentiated instruction, or adapting materials to suit the diverse needs of individual learners [15, 24]. T5 *"thought it would be nice to have a version to support students with lower reading comprehension levels or less background knowledge."* Participant T3 compared her experience as a blind

[1] Students in educational stages ranging from Kindergarten to 12th grade.
[2] https://code.visualstudio.com/docs/configure/accessibility/accessibility

individual to those of students to articulate the specialized assistance she would expect: *"As a student, being able to use this website efficiently is to have some sort of step-by-step cheat sheet."*

The impressions of navigation difficulty by sighted teachers may differ from individual users' needs. Participants T2 and T4 stated that JAWS navigation with EarSketch felt cluttered due to the large number of available panes. Participant T3 (herself blind) disagreed, stating that *"being a person who's blind, I didn't get all of the extra clutter on the page"* by focusing only on the necessary elements (switching between the Sound Browser and Code Editor).

3.2.2 Scaffolding to Support Learner Independence. The teachers highlighted that a tenet of their curricula is preparing students for independent work by scaffolding material to accommodate their often widely varied abilities [4]. Participants T1 and T5 emphasized how EarSketch could better help students move beyond their current abilities, citing how widening the Zone of Proximal Development [35] can encourage independent problem-solving and exploration for learners who are BVI [14, 23]. T5 highlights the importance of adding information to EarSketch's built-in curriculum that supports learning skills for learners who are BVI: *"When we teach about screen readers, we would like to have the students know why it interacts with things the way that they do... if there's no expansion on why that is, then they just have this tiny subset of the information."* T2 compared EarSketch's presentation of concepts in gradually increasing complexity to the physical coding interface Code Jumper[3], with which they began with simple musical phrases so that "it doesn't get too complicated right off the bat." However, accessible technology tools like Code Jumper and Skoog[4] face issues due to their cost and use of less "authentic" industry-relevant languages than EarSketch's Python and JavaScript code.

4 Student Co-Design

We performed an in-person co-design study with students in October 2024 to explore how EarSketch could be adapted to better support learners who are BVI. While the teacher study provided pedagogical insights, this student co-design aims to center the learners themselves as direct contributors, uncovering their ideas, preferences, and challenges in real-time use – i.e., how students envision adapting the EarSketch platform to meet their needs better [20]. Our extended goal was to uncover design implications grounded in the lived experiences of EarSketch users who are BVI, extending both the teacher-informed findings and the applicability of our work to other expressive CS learning environments.

4.1 Study Design

The six participants in this study (5 male, 1 female, ages ranging from 15 to 18) have various levels of visual impairment and experience with assistive technology (see Appendix Table 3). Their teachers chose them to participate in this study, as they were students in a course designed to teach computer literacy skills and the use of assistive technology. The students were all novice programmers, except one (S6) who had an intermediate level of programming expertise. Three students used a screen reader (S2, S4, S6), two used a screen magnifier (S3, S5), and one used both (S1).

[3]https://codejumper.com/
[4]https://accessible-tech.org/skoog/

This study took place over four days at their school (see Appendix Table 4). On the first day, students were guided through a version of EarSketch modified based on recommendations from the teachers in the previous study (see Figure 2 in the Appendix). This version included a permanently available list of keyboard shortcuts, added shortcuts for playing and pausing a project, and removed the site's collapsible panes to ease the use of keyboard navigation. The students created EarSketch projects on the second and third days, with instructions to use a variety of sounds and functions from the EarSketch API. The co-design session on the fourth day aimed to gather student perspectives on EarSketch. In a Think-Pair-Share exercise [16], student pairs presented their favorite and least favorite technologies. The students then designed prototypes for "an improved EarSketch interface," utilizing a tactile graphic representation of EarSketch. Students then completed a speculative design activity [1] to develop ideas for a "brand-new EarSketch."

We began analysis by collecting observational logs and artifacts, such as the prototypes designed by students, and comparing the language used by the students with the codes and themes from the previous study. We then synthesized the data using affinity mapping [18] into themes that offer wider guidance for accessible expressive CS learning environments. This iterative process grounded the analysis in empirical insights derived from the co-design sessions.

4.2 Student Co-Design Findings

We grouped our findings from the student co-design into the following two themes: (1) challenges in information retrieval speed due to sequential navigation constraints and (2) the opportunity cost of navigating across panes.

4.2.1 Challenges in Information Retrieval Speed due to Sequential Navigation Constraints. EarSketch's sample-based music production is optimized for visual scanning, creating difficulties for screen reader/magnifier users who must process information serially. For example, screen reader users must listen to each sound in the Sound Browser's name read aloud individually. Because the Sound Browser lacked hierarchical navigation headings, Participant S2 was required to try all of the available filter options in sequence to select sounds and had to manually select each filter option to determine its status. As a novice screen reader user, S2 required sighted assistance to aid his navigation of the filters.

Teacher participant T2 expressed concern about incremental learning opportunities being lost as a result of these challenges. Student participants suggested contextual, auditory feedback that circumvents these issues for a speedier workflow. For instance, participant S4 suggested a key command to list and verify the state of filters.

4.2.2 Opportunity Cost of Multitasking Across Panes. The students faced an *opportunity cost* of navigating to and from the Code Editor. Because JAWS screen reader navigation uses key commands, students accidentally edited their code while navigating. For example, all screen reader users used the "tab" key to change headings with JAWS, but also added unintentional tab indentation blocks within the Code Editor. Manually checking for these accidental changes without visual confirmation requires students to navigate back to the Code Editor and hear the code read aloud in full. This tension highlights how the EarSketch interface assumes the ability to multitask efficiently across visual elements.

Sighted users such as participant T1 seamlessly switched between the Code Editor and DAW, using changes in DAW waveforms to *"confirm that (he) did the code correctly"* and *"as a gauge for where (he) was placing sounds."* However, screen reader users largely ignored the DAW because it was not navigable using JAWS. Similarly, screen magnifier user S5 had to navigate between the Code Editor and DAW panes multiple times to confirm changes were applied. S3 explored the DAW, but could not view it in tandem with her code and could not rely on it to confirm a project's successful compilation. Participant S1 expected auditory feedback as confirmation that his script ran correctly or incorrectly. Screen magnifier users S3 and S5 sometimes could not tell if their code had an error because the error notifications were in separate corners of the screen, far from their focused magnification. A lack of feedback within the Code Editor resulted in numerous errors that required sighted support to resolve. This hindered S3's and S4's ability to work independently: they relied on their teacher to visually confirm code changes, then continued to have the teacher auditorily confirm musical changes. Participants provided suggestions to address this issue by circumventing navigation. Participants S1 and S2 designed a prototype based on iOS applications that focused on one aspect of EarSketch at a time, such as the Sound Browser. Participant S4 suggested *"universal search"* [32], using text queries to automate navigation.

5 Discussion & Future Work

In this paper, we investigate the opportunities and accessibility barriers that emerge when learners who are Blind and Visually Impaired (BVI) engage in creative computing through the EarSketch expressive computer science learning environment. Through co-design studies with learners who are BVI and their teachers, we observed how learners navigate and engage with the platform, finding that they are intrinsically motivated in their tasks and personally invested in the artifacts they create, encouraging independent problem solving and exploration. However, the students faced navigational challenges due to the serial workflows imposed by areas in which EarSketch's visually-focused design did not fully accommodate the use of assistive technology. These issues were at a lower, more mechanical level than those anticipated by the teachers, such as navigating lists of options or between side-by-side panes. Experienced screen reader users like the teachers were able to find effective workflows quickly, but these issues were particularly detrimental to the less experienced students who do not have screen reader controls memorized. These barriers introduce additional time costs and cognitive overhead, often shifting focus away from creative exploration and learning goals.

In future work, we will engage in additional co-design sessions with learners who are BVI to inform iterative accessibility improvements in EarSketch to support creativity, multitasking, and independence through efficient keyboard navigation of its music and coding elements. We plan to evaluate EarSketch in order to identify patterns for accessible navigation of multimodal computing systems. Our goal is to promote learner agency and encourage independent engagement in creative computing by reducing the disproportionate effort currently required of learners just to access and operate the environment. We also aim to collaborate with teachers to develop curricula that will allow them to meaningfully integrate EarSketch in their BVI classrooms. We hope that our methodologies and findings will support ongoing efforts to improve accessibility in existing expressive CS learning environments, while contributing to the design and adoption of more accessible creative computing platforms tailored to the needs of BVI learners.

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References

[1] James Auger. 2013. Speculative design: crafting the speculation. *Digital Creativity* 24, 1 (2013), 11–35.
[2] Victoria Clarke and Virginia Braun. 2017. Thematic analysis. *The journal of positive psychology* 12, 3 (2017), 297–298.
[3] Andrew Csizmadia, Bernhard Standl, and Jane Waite. 2019. Integrating the constructionist learning theory with computational thinking classroom activities. *Informatics in Education* 18, 1 (2019), 41–67.
[4] Elizabeth A Davis. 2000. Scaffolding students' knowledge integration: Prompts for reflection in KIE. *International Journal of Science Education* 22, 8 (2000), 819–837.
[5] Shi Ding, Jason Brent Smith, Stephen Garrett, Jason Freeman, Bryan Pardo, Stephanie Ludi, Taneisha Lee, and Tom McKlin. 2025. EarSketch Codebook for Accessible and Expressive Computer Science Education. https://hdl.handle.net/1853/77630. Published via Georgia Tech Institutional Repository.
[6] Shi Ding, Jason Brent Smith, Stephen Garrett, and Brian Magerko. 2024. Redesigning EarSketch for Inclusive CS Education: A Participatory Design Approach. In *Proceedings of the 23rd Annual ACM Interaction Design and Children Conference*. 720–724.
[7] Shi Ding, Jason Brent Smith, and Brian Magerko. 2025. Considering Large Language Model Integration in Expressive Computer Science Learning Environments for Blind and Visually Impaired Learners Through Co-design. In *International Conference on Artificial Intelligence in Education*. Springer, 472–480.
[8] Vladimiras Dolgopolovas, Valentina Dagienė, Eglė Jasutė, and Tatjana Jevsikova. 2019. Design science research for computational thinking in constructionist education: a pragmatist perspective. *Problemos* 95 (2019), 144–159.
[9] 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.
[10] Stefano Federici and Linda Stern. 2011. A constructionist approach to computer science. In *Global Learn*. Association for the Advancement of Computing in Education (AACE), 1352–1361.
[11] Adrian Florea, Arpad Gellert, Delilah Florea, and Adrian-Cristian Florea. 2016. TEACHING PROGRAMMING BY DEVELOPING GAMES IN ALICE. *eLearning & Software for Education* 1 (2016).
[12] 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.
[13] 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)*.
[14] Laxmi Gunupudi, Maryam Bandukda, Giulia Barbareschi, Tigmanshu Bhatnagar, Aanchal Singh, Satish Mishra, Amit Prakash, and Catherine Holloway. 2024. Scaffolding Digital Literacy Through Digital Skills Training for Disabled People in the Global South. In *Proceedings of the 26th International ACM SIGACCESS Conference on Computers and Accessibility*. 1–14.
[15] Carla Haelermans. 2022. The Effects of Group differentiation by students' learning strategies. *Instructional Science* 50, 2 (2022), 223–250.
[16] Mahmoud Kaddoura. 2013. Think pair share: A teaching learning strategy to enhance students' critical thinking. *Educational Research Quarterly* 36, 4 (2013), 3–24.
[17] Börje Langefors. 1978. Analysis of user needs. In *Conference of the European Cooperation in Informatics*. Springer, 1–38.

[18] Andrés Lucero. 2015. Using affinity diagrams to evaluate interactive prototypes. In *Human-Computer Interaction–INTERACT 2015: 15th IFIP TC 13 International Conference, Bamberg, Germany, September 14-18, 2015, Proceedings, Part II 15*. Springer, 231–248.

[19] 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.

[20] 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.

[21] 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.

[22] Oussama Metatla, Alison Oldfield, Taimur Ahmed, Antonis Vafeas, and Sunny Miglani. 2019. Voice user interfaces in schools: Co-designing for inclusion with visually-impaired and sighted pupils. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*. 1–15.

[23] Lisa N Michaud, Kathleen F McCoy, and Christopher A Pennington. 2000. An intelligent tutoring system for deaf learners of written English. In *Proceedings of the fourth international ACM conference on Assistive technologies*. 92–100.

[24] Martin Mills, Sue Monk, Amanda Keddie, Peter Renshaw, Pam Christie, David Geelan, and Christina Gowlett. 2014. Differentiated learning: From policy to classroom. *Oxford review of education* 40, 3 (2014), 331–348.

[25] Konstantinos S Papadopoulos and Dimitrios B Goudiras. 2005. Accessibility assistance for visually-impaired people in digital texts. *British journal of visual impairment* 23, 2 (2005), 75–83.

[26] William R Penuel. 2019. Co-design as infrastructuring with attention to power: Building collective capacity for equitable teaching and learning through design-based implementation research. *Collaborative curriculum design for sustainable innovation and teacher learning* (2019), 387–401.

[27] Kevin Proudfoot. 2023. Inductive/deductive hybrid thematic analysis in mixed methods research. *Journal of mixed methods research* 17, 3 (2023), 308–326.

[28] 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.

[29] Abir Saha, Thomas Barlow McHugh, and Anne Marie Piper. 2023. Tutoria11y: Enhancing Accessible Interactive Tutorial Creation by Blind Audio Producers. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*. 1–14.

[30] Abir Saha and Anne Marie Piper. 2020. Understanding audio production practices of people with vision impairments. In *Proceedings of the 22nd International ACM SIGACCESS Conference on Computers and Accessibility*. 1–13.

[31] Jorge Sassaki Resende Silva, Paula Christina Figueira Cardoso, Raphael Winckler de Bettio, Daniela Cardoso Tavares, Carlos Alberto Silva, Willian Massami Watanabe, and André Pimenta Freire. 2024. In-Page Navigation Aids for Screen-Reader Users with Automatic Topicalisation and Labelling. *ACM Transactions on Accessible Computing* (2024).

[32] Laurianne Sitbon, Lauren Fell, David Poxon, Jinglan Zhang, and Shlomo Geva. 2014. Towards universal search design. In *Proceedings of the 19th Australasian Document Computing Symposium*. 109–112.

[33] Clay Spinuzzi. 2005. The methodology of participatory design. *Technical communication* 52, 2 (2005), 163–174.

[34] Anselm Strauss. 1987. Qualitative analysis for social scientists. *Cambridge University* (1987).

[35] Lev S Vygotsky. 1978. *Mind in society: The development of higher psychological processes*. Vol. 86. Harvard university press.

A EarSketch Interfaces

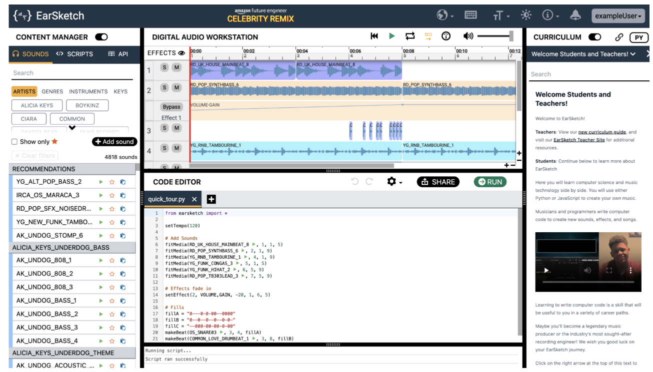

Figure 1: The EarSketch web client interface with a) the Content Manager (left)–containing the Sound Browser, Script Browser, and API; b) a Digital Audio Workstation (top); c) the Code Editor (bottom); and d) the Curriculum (right). This was the interface presented to the teachers in their co-design workshop.

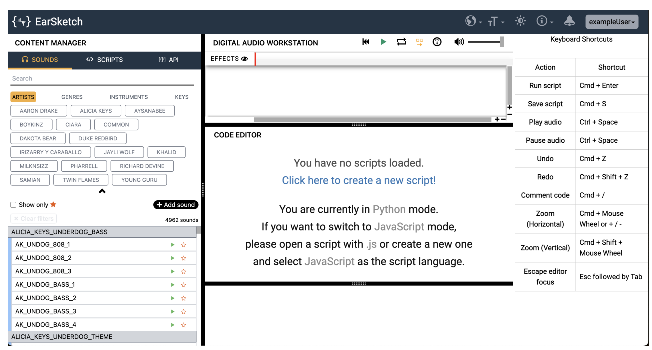

Figure 2: The feedback from the teacher co-design workshop led to this modified EarSketch web client. This interface was used during the student co-design session. Keyboard shortcuts (right) were displayed instead of the standard Curriculum to allow for increased access to necessary shortcuts.

B Tables

B.1 Teacher Co-Design

Participant	Gender	Subject	Grade	Years Teaching	Years at Current School	Visual Acuity
T1	Male	Assistive Technology	9th-12th	7	7	Visually Impaired
T2	Female	Assistive Technology	9th-12th	11	11	Sighted
T3	Female	Assistive Technology	K-12	23	4	Blind
T4	Female	Assistive Technology	K-12	5	5	Sighted
T5	Female	All Technology	9th-12th	10	10	Sighted

Table 1: Demographic Characteristics of Teacher Participants

Date(s)	Activity	Description	Research Objective
4/23/24 (1 hour)	Onboarding Session	Overview of EarSketch and its features using a recorded tutorial and demonstration of example projects.	Learn the initial impressions of teachers when introduced to an expressive CS learning environment.
4/24/24 - 4/25/24 (2 hours)	Homework Task	Participants created projects in EarSketch asynchronously.	Learn how teachers adapt to using EarSketch and identify potential accessibility barriers.
4/26/24 - 5/08/24 (1 hour)	Individual Interviews	Discussions about incorporation of technology in participants' classrooms.	Learn how teachers view expressive CS learning environments as tools to engage learners who are BVI.
5/10/24 (3 hours)	Group Co-Design	Discussions about EarSketch's accessibility, how they may integrate it into their curricula, and what the needs of learners who are BVI using it are.	Learn how teachers integrate expressive CS learning environments into their curricula, the strengths and weaknesses of EarSketch in a BVI classroom, and how to prepare activities/materials for co-design with students.

Table 2: Session schedule and research objectives for the teacher co-design study.

B.2 Student Co-Design

Participant	Gender	Age	Ethnicity	Assistive Tech. Used	Proficiency
S1	Male	16	Hispanic	Screen Reader/Magnifier (JAWS/Windows)	Intermediate/High
S2	Male	16	Hispanic	Screen Reader (JAWS)	Beginner
S3	Female	18	Hispanic	Screen Magnifier (MacOS)	High
S4	Male	16	Hispanic	Screen Reader (JAWS)	Intermediate
S5	Male	16	White	Screen Magnifier (ZoomText)	Beginner
S6	Male	15	White	Screen Reader (JAWS)	High

Table 3: Demographic Characteristics of Student Participants.

Date	Activity	Description	Research Objective
10/07/24 (45 minutes)	Introduction to EarSketch	Overview of EarSketch, its features, and a project demonstration.	Learn how learners who are BVI navigate EarSketch.
10/08/24 (45 minutes)	Hands-On Project Creation	Guided creation of a basic EarSketch project.	Learn how learners who are BVI interact with the code editor.
10/09/24 (45 minutes)	Self-Exploration	Independent work on expanding projects, applying and reinforcing skills.	Learn the workflows of learners who are BVI while using EarSketch.
10/11/24 (3 hours)	Prototype Design and Presentation	Developing and presenting prototypes and speculative designs for more accessible expressive CS learning environment.	Receive idealized design paradigms for workflow with a more accessible EarSketch and gather feedback on EarSketch as it exists now.

Table 4: Session schedule and research objectives for the student co-design study.