Co-Designing Accessible Science Education Simulations with Blind and Visually-Impaired Teens

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ABSTRACT

Design thinking is an approach to educational curriculum that builds empathy, encourages ideation, and fosters active problem solving through hands-on design projects. Embedding participatory "co-design" into design thinking curriculum offers students agency in finding solutions to real-world design challenges, which may support personal empowerment. An opportunity to explore this prospect arose in the design of sounds for an accessible interactive science-education simulation in the PhET Project. Over the course of three weeks, PhET researchers engaged blind and visually-impaired high-school students in a design thinking curriculum that included the co-design of sounds and auditory interactions for the Balloons and Static Electricity (BASE) sim. By the end of the curriculum, students had iterated through all aspects of design thinking and performed a quantitative evaluation of multiple sound prototypes. Furthermore, the group's mean self-efficacy rating had increased. We reflect on our curriculum and the choices we made that helped enable the students to become authentic partners in sound design.

CCS CONCEPTS

• **Human-centered computing → Accessibility design and evaluation methods**; *Accessibility systems and tools.*

KEYWORDS

Design Thinking, Co-Design, Participatory Design, Sonification, Auditory Display, Teens, Visually-Impaired, Blind, Science Education, Simulation

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1 INTRODUCTION

Since 2002, the PhET project (http://phet.colorado.edu) has created nearly 200 free online interactive science and math simulations ('sims') for K-13+ STEM learning that are used more than 100 million times per year all over the world. Until recently, these sims were not accessible to learners with visual impairments. PhET has been working to increase the accessibility of its sims by incorporating alternative input capabilities, audio description, and sonification [17, 19, 21]. The PhET accessibility design process has typically involved collaborating with accessibility and inclusive design experts early on to create accessible sim prototypes, and then bringing in potential end users (e.g., visually-impaired learners) later in the process as prototype testers. More recently, PhET has begun to explore an accessibility design process that includes the end users (i.e. students) in a participatory "co-design" processes [8]. To support these students as full design partners, co-design activities are embedded in a larger design thinking curriculum.

1.1 Design Thinking and Co-Design with BVI Teens

Design Thinking is a approach to educational curriculum that builds empathy, encourages ideation, and fosters active problem solving through hands-on design projects [1]. Crucial to design thinking is its semi-structured approach to problem solving and design involving an iterative process of five key components—empathize, define, ideate, prototype and test—that are applied from start to finish [2, 10]. For the purposes of our research, we embedded a real-world design challenge into our design thinking curriculum, enabling blind and visually-impaired teens to participate as full partners in a mutually-beneficial co-design process [3, 16]. In addition to solving design problems, prior work has argued that these design processes can also develop positive personal characteristics such as cooperation, curiosity, creativity, reflexivity and empowerment [18, 20]. As the curriculum we developed was part of a larger empowerment program, we used a self-efficacy survey to assess if students' sense of empowerment increased after completing the curricula.

Co-designing with teens requires sensitivity to their unique personal and developmental motivations for participation such as autonomy, individual identity, exploration, risk taking, and time with peers [5, 7, 9, 11]. Prior work on co-design with blind and visually-impaired (BVI) people has incorporated children and adults (e.g. [12, 13]), but work with teens has been rare [15]. A small body of recent research has begun to explore methods for sonification co-design [6, 22], but investigations into their application with BVI persons have thus far been limited to adults (e.g. [14]). Thus engaging BVI teens in sonification co-design required a creative curriculum that attracted their unique motivational drives, and enabled prototyping with accessible sound technologies.

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2 METHODS

2.1 Context

Researchers partnered with the Louisiana Center for the Blind (LCB) to develop and administer a sound design and design thinking curriculum to visually-impaired high-school students enrolled in a summer growth and empowerment program.[1] Participants were high school students (4 boys and 2 girls) between 16-20 years old from all over the USA. Although the students had varying levels of visual impairment, all students used screen readers when using technology such as smartphones and computers. PhET researchers developed the overall structure of the curriculum, adapting from prior Design Thinking and co-design activities with students with learning disabilities [8], and two PhET researchers co-facilitated students each day. This curriculum was delivered in twelve two-hour increments broken into three multi-day segments (i.e. 3 days, 5 days, 4 days) with week-long breaks in between, for a total of five weeks. The curricula and co-design was geared towards sound design for Balloons and Static Electricity (BASE), a sim where users explore the phenomena of static electricity by rubbing a sweater on a balloon.[2] Prior work had made BASE accessible to screen-reader users [17], which enabled the students to explore the sim before beginning sound design.

2.2 Curriculum

The curriculum began with an introductory activity called the Five Chairs Challenge—a hands-on activity that teaches the five stages of design thinking through the design of chairs for fictional people. Typically this activity uses predefined people (e.g. characters from "The Simpsons"), but we modified the activity to allow characters from the students own imagination. This modification targeted the unique psychological motivations of teenagers related to risk taking, exploration, identity construction and socialization (e.g. [4]), and also provided an opportunity for the researchers and students to get to know each other and build mutual trust. These introductory sessions concluded with an introduction to sound design and sonification on day three—a learning activity designed to peak their excitement and interest in sound design before beginning the real-world design challenge of auditory interactions for BASE.

The second segment of the curriculum applied design thinking to create multiple prototype sounds for BASE. After familiarizing the students with PhET and the existing accessibility sound features, we introduced them to BASE through a hands-on activity where they tried to get balloons to stick to walls in the common area. We used this fun and tangible experience to explain the underlying physics of the simulation (e.g. static electricity, positive and negative charges). The students then used this knowledge to define the problem and collectively decide i) what concepts in the sim needed sonification and ii) what were the objectives the sounds should achieve (e.g. be informative, engaging, fun). We then re-introduced them to ideation with a modified version of the Alternate Uses Task, which taught divergent thinking by prizing the number of student responses. The students then separated into three groups of two and applied ideation to prototype many sound ideas for each of the chosen concepts in the sim. These sounds were then reviewed by the group as a whole and evaluated to determine the "top-three" sound design choices for each concept.

The third segment focused on the testing/evaluation portion and the selection of the "best" sound for each of the concepts. Students listened to the finalized versions of each sound prototype, which had been embedded in the sim by PhET developers after the second segment. Students then provided a quantitative evaluation of each of the three sounds for each concept—rating the degree to which each sound met the sound objectives that were established in the second segment. The sound with the best overall score was put into a final version of the sim representing a final "deployment." The last segment also included three hour-long discussions with members of the PhET accessibility research team, which connected the design activities that students had been doing to real-world design and research work. More detailed information about this curriculum, activities, data analysis and sound designs are available online.[3]

[1]More information on the STEP Program: http://www.louisianacenter.org/step

[2]Play with BASE here: https://phet.colorado.edu/en/simulation/balloons-and-static-electricity

3 RESULTS & DISCUSSION

Given prior research that has associated design thinking and co-design with empowerment [18, 20], we decided to administer a 10-question self-efficacy survey at the beginning and end of the co-design activity. On both occasions, we asked students to consider each question thoroughly and answer as accurately as possible without being influenced by the instructors. Upon analysis of the data, we found that five out of six students reported higher self-efficacy ratings on the second administration (i.e. after sound design), and the groups' mean self-efficacy increased by 8.3%. A one-tailed paired t-test of participants' average response to the survey did not reach significance ($p = 0.21$). Because the data sample is small (i.e. $N = 6$), future work might achieve statistical significance by including more participants. These quantitative results would further support the argument that co-design and design thinking are processes promoting empowerment.

As part of the "Empathize" portion of design, we contrasted PhET sims that included both screen-reader accessible auditory descriptions and non-speech sounds with the current version of BASE, which included auditory descriptions only. We asked students to reflect upon the differences between the two types of auditory feedback. Students reflected that the sims with sound feedback were engaging and fun, while BASE was "boring" and "disappointing" because it did not (yet) have sounds. We believe these comments strongly support the rational for applying non-speech audio (i.e. sonification) as a complement to spoken accessibility features. We believe interactive sounds will increase motivation through engagement and fun, and may produce a similar effect in sighted students as well.

3.1 Co-Design Strategies

Co-design disrupts the typical design workflow by incorporating non-specialist "users" into decision making, which can create radically different design results and trajectories. In our case, we took a risk early in our co-design by asking the students which concepts and interactions in BASE should have sounds. We believed that

[3]Supplemental materials are available online: https://tinyurl.com/yyc7bgq7

making this choice would give students essential ideation experience and also establish their agency and equality as co-designers. However, PhET had previously done research and identified three concepts that should have sounds. A difference between these answers could have created a conflict between the needs of the PhET research team and an authentic co-design process. Fortunately, we found that the students identified the same three concepts as the PhET research team, but future researchers should be aware that authentic co-design can sometimes conflict with pre-defined design or research agenda. We recommend that future researchers seek to understand the scope and value of these differences in the co-design process, and determine how to navigate them prior to the start of co-design.

3.2 Key Accommodations

In addition to the differences in visual ability between the students and co-design instructors, there were also differences in experience with sound design. To accommodate these differences and help students prototype sounds, we decided to use a simple and tangible sound technology—the hand-held sound recorder. These devices are the swiss-army knife of sound design, including microphones, speakers, sound storage, and simple, tangible interfaces for sound playback. These devices helped students record sounds, including those they found by searching the internet (e.g. YouTube), and complement them with verbal descriptions and explanations. The devices were also essential to sharing sounds with the larger group—an act that enabled discussion and evaluation. They also enabled PhET developers to quickly create and deploy high-quality versions of each sound prototype for the final evaluation. Because we found these devices so useful, we would recommend external hand-held recorders for a broad range of sound co-design challenges.

4 CONCLUSION & FUTURE WORK

The curricula and knowledge described in this paper come from the first round of research by the PhET Project into methods for engaging and enabling students to participate in a sonification co-design process. Although there are many more insights that can be offered presently, we have limited the scope to focus on those we believe will be most important for future work. Enabling non-experts to become authentic design partners requires an education on design processes, and design thinking provides a excellent framework in this respect. Successful co-design with any population requires sensitivity to the unique motivations driving their participation and prototyping technologies that cater to their abilities. Our preliminary evidence suggests that students feelings of empowerment increased following their participation, but other positive attributes might have increased as well (e.g. [18]). Future research should verify this hypothesis in a more controlled manner with greater numbers of students.

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