Abstract

Online technology and digital media have provided space for students to participate and express their voices over the last two decades. This paper further explores how new digital technologies, such as humanoid robots and wearable electronics, can be used to offer additional spaces where students' voices are heard. In these spaces, young students are invited to shape the design of digital tools and artifacts through the inclusion of their unique perspectives. The authors argue that involving youth in the design and use of tools contributes not only to the creation of meaningful learning experiences but also to the future potential of youth as producers of digital learning technologies.

Keywords: Student voice, Interactive technology design, Digital making, Human-robot interaction, Inclusive contexts.

Empowering Student Voice through Interactive Design and Digital Making

Since the early 1990s, a number of educators have argued for the inclusion of student voice in educational research, practice, and policy (Fielding, 2004). Student voice is used as a collective term that expands the sound of student speaking to represent the "presence, participation, and power" of students in relation to other people, practices, and institutions (Cook-Sather, 2006, p. 4). Research in student voice seeks to amplify youth voices in educational contexts so as to promote transformative learning experiences. The interest in student voice and digital technology has focused on how youth express themselves in a variety of technology-based environments (boyd[1], 2015; Kafai & Burke, 2014; Korobkova & Black, 2014). Here, by student voice, we refer to the incorporation of youth's perspectives in the design and use of digital technologies, with a particular focus on the incorporation of multiple perspectives to make educational experiences more equitable for diverse learners.

In this paper, the authors show how students can participate in the design and implementation of digital technologies beyond the screen. By moving from primarily consumers of digital technology to key participants in design and making, youth are more likely to be engaged in learning. Two cases of youth's participation are described through the lens of student voice. The first case involves the design of robot/child interactions for preschool to kindergarten-aged children who start to learn English language and literacy. It illustrates how interactive design processes with children have enabled designers to understand the children's perspectives (based on their reactions to the on-going designs), resulting in engaging robot-based language learning. The second case involves the use of wearable electronic technologies by American Indian youth (12-14 years old). The technologies have enabled students to draw upon heritage cultural practices, such as weaving,

[1] Purposefully lowercase.

in the design of digital artifacts. Engaging in this process not only supports students' cultural identities but also empowers them as learners who are able to contribute unique resources to their classrooms.

Theoretical Background

Engaging Student Voices for Transformative Experiences

Research in student voice draws attention to youth's unique knowledge and perspectives on their school and life experiences. In this approach, the voice of students is respected as a catalyst to effect educational endeavors. In educational reform, students are considered "active stakeholders" (Cook-Sather, 2014, p.139) to bring about transformative learning experiences (Kirshner, 2015). In educational research, students are included as co-researchers who actively participate in all aspects of research design and implementation (Cammarota & Fine, 2008; Fielding, 2004). Allowing space for students' voices not only facilitates students' awareness of their environments (Carrington, Allen, & Osmolowski, 2007) but also empowers them to develop a sense of agency, belonging, and competence (Mitra & Serriere, 2012). Indeed, a number of studies over the last decade have shown that student involvement is a powerful and effective force for engaging students in productive educational experiences and school improvement (Carrington, et al., 2007; Mitra, 2004).

Student Voice and Digital Technology

Digital technology has provided spaces where students participate and communicate their experiences. Students use digital media to express their voice in multimodal narratives, such as digital photos, comic strips, and video diaries (Nind, Boorman, & Clarke, 2012). Students' visuals present a detailed portrait of student experiences, enabling researchers and teachers to better understand the complexities of students' perceptions of their schooling (Carrington, et al., 2007; Nind, et al., 2012). Each medium not only affords a unique pattern of student participation but also allows the students to use different modalities to express who they are.

More recently, new technologies enable the integration of physical space with digital space, opening up additional arenas that amplify student voice (Kafai, Fields, & Searle, 2014). For example, students sew electronic textiles with a needle and conductive thread and then program them on a computer, which engages the students in learning circuitry and computing while creating a textile artifact that expresses some aspect of their identities. Computational tools like Scratch invite young students to create interactive stories, music videos, and games that connect to their interests and identities (Brennan & Resnick, 2012). Also, online virtual tools provide spaces where students participate inside and outside school at any time and at a large scale beyond the local context (Risquez, Raftery, & Costello, 2015).

The authors ask how we can design and implement emerging technological tools in such a way that empowers young learners, so that they can meaningfully benefit from the educational tools. While today's youth abound with everyday technologies, their technology use typically involves consuming technology in rote ways rather than producing it (Warschauer & Matuchniak, 2010). In this article, we explored two ways in which youth played a key role in the design of digital learning tools as they employed digital tools to produce new artifacts and contributed to the learning activities.

New Digital Technologies for Supporting Student Voices: Two Cases

Case 1: Interactive Design of Digital Tools

Background: Designing with children

Young children learn while they play together and with tools, influencing their capabilities and affordances mutually (Salomon, 2001). After observing preschool-aged children's behavior while they play, Gopnik (2012) concluded that the children develop their own intuitive theories of their worlds, test hypotheses, and make inferences based on their observations of surroundings. A sense of agency and autonomy is crucial to make room for children's experimentation and occasional failure (Blumenfeld, Kempler, & Krajcik, 2006). Respecting children's autonomy not only facilitates their learning but also leads them to build quality relationships (Hamre, Hatfield, Pianta, & Jamil, 2014). From this, we infer that the design of educational tools for children might not necessarily be prescribing regimens for effective learning processes. Both designers and children should be involved in a dialogic process to produce engaging tools. Not surprisingly, design may evolve as designers continually correct the designs while listening to children's autonomous responses.

In this dialogic design process, children are considered not merely as the target of the design but as active informants contributing to design decisions. Generally, expert designers begin with an initial design, where they intend to speak *for* the children in support of their learning (Fielding, 2004). It is also important, however, for designers to speak *with* children when children participate in the designed activity. Here, designers might be repositioned as listeners to children's voices, i.e., revisiting their designs while eliciting children's behavior. Tangen (2008) views listening "as an active process of exchange of meanings" (p. 159) using more than what children say. Through active listening, a designer closely observes how children react to the design: identifying what assumptions held by the designer should be corrected and what kinds of support should be further provided to create more engaging experiences with the designed tool. Through this mindful observation, the designer might be able to readily reconstruct and refine their designs as necessary. This partnership between the designer and children allows them to be mutually informative and co-generate solutions that are more engaging and more imaginative. The productive partnership between designers and children is illustrated in the following design project that has developed robot-based learning apps.

The robot and design context

The embodied robot (see Figure 1) used in the project was equipped with a screen on the head and optical and touch sensors on the body. The robot was able to nod its head and move around using the wheels on its feet. When the robot talked, the relevant content was also presented on the screen. The children interacted with the robot using the touch screen or the sensors on its body. The role of the robot was defined as a playmate, and children learned the topic as they played with the robot.

The robot-based app was designed to teach the names of colors and shapes and letter-sound match to preschool to kindergarten-aged children who learned English as a second language (Kim & Smith, 2017). Three learning activities (songs, games, and a book) played a specific role in mastery of three objectives: learning the names of basic shapes (triangle, circle, square, and rectangle) and basic colors (red, orange, yellow, green, blue, and purple) and identifying initial consonant sounds. The activities built on each other. The song introduced children to the target vocabulary and letter-sound match. The children played games with the robot, which reinforced the topic introduced in the songs. The book extended what children had already learned by using a story that gave new context to the topic.

Our design goal was to create engaging robot-assisted learning experiences. Over a four-month period, the designers worked with eleven children (four to six years old) individually in school, and at home in multiple iterations of initial design, user testing, and refinement. The children lived in the United States and spoke little to no English. The focus of user testing was on evaluating ease of navigation and children's engagement and learning as they interacted with the robot. The interactions with the robot were video recorded and later discussed in the design team meetings, the results of which led to design refinement.

Key lessons and implications

One of our design intentions was to program the robot to make a path in a specific shape (e.g., triangle or square) while it sang a shape song. However, we faced an unexpected challenge. The speed of the wheels on the robot's feet changed depending on the surface of the floor where it was placed. On carpet, they slowed down; on a smooth floor like hardwood or linoleum, they moved faster. We expended a lot of effort defining the right parameters to work across different floor types but could not find a perfect solution. We took our design in progress to the children, putting the robot on the floor and letting them explore the robot's features and the learning activities. We tried to minimize influence from the designers while the children explored and made voluntary choices. Surprisingly, it did not matter to children if the robot drew a perfect shape or not. Although the robot's movements were not perfect, the child paid attention to the robot and followed the robot in more active, playful ways, as illustrated below. This response helped us stop worrying about an ultimately unnecessary feature. More importantly, it helped us learn that we had been inadvertently bound to the adult expectation that children would interact face to face with the robot in one position.

> **Robot:** Sings a Triangle song and moves to draw a triangle. As it finishes singing, it stops in another place on the floor.
>
> **Girl:** Crawls to follow the robot while singing along and stops in the same place the robot stops.
>
> **Robot:** Sings a Circle song. Its movements are narrower this time. As it finishes singing, it stops facing another direction.

Girl: Watches the singing robot. As it finishes singing and moving, she turns the robot to face her.

In another instance, the robot's proximity sensors were used as a channel for interaction. While playing a game with the robot, children responded by putting a hand close to the robot's eyes where the proximity sensors were located. But the children gradually moved closer and closer toward the robot as they engaged in the play. This shortened distance overloaded the sensors and confused what was scripted for that program.

Designer guides the boy to sit a short distance from the robot on the floor and introduces how to play the game using the proximity sensor.

Boy: As he continues with the game, he gradually moves toward the robot.

Robot: Responds unexpectedly and runs amok.

Designer stops the boy and directs him to keep distance from the robot

Boy: Quickly forgets about the designers' instructions. Reaches his arm to touch the robot's body parts and even *tries to hold the robot with his arms.*

The designers had overlooked children's natural tendency to move toward an object they were engaged with, mistakenly assuming that children would maintain a constant distance throughout play. This observation led us to disable the proximity sensors and instead use another mode for interaction.

(Insert Figure 1 about here.)

Our designers started with a thorough review of learning and development theories. Nonetheless, it became obvious that the design details could be established only through carefully listening to children while they actively participate in the designed interactions. An important lesson was that efficacious design was essentially a process of engaging and legitimating children's voices (Mockler & Groundwater-Smith, 2015), leading to interactive decision-making. Children's reactions to the designs and the way they interacted in a natural setting should guide the design decisions. This way the designed product might be better fit to personalized, transformative learning experiences.

Case 2: Youth's Making Digital Artifacts

Background: Culturally responsive computing

As the number of culturally and linguistically diverse (CLD) students in classrooms has grown worldwide, educators have increasingly focused on creating inclusive environments where the voices of all students are equally valued and respected for their varied knowledge and experiences (Carrington, et al., 2007). Aligned with an emphasis on voice, culturally responsive approaches to schooling emphasize the importance of curricula, pedagogy, and policy that *make sense* to learners from a particular cultural group (Gay, 2010; Ladson-Billings, 2009). Culturally responsive approaches to schooling move beyond valuing the voices of marginalized students to engaging them as active participants critically inquiring into and designing their learning experiences (Rodríguez & Brown, 2009). Through such an approach, students' cultural backgrounds come to be seen as a resource for classroom learning.

Recent technological developments merging physical and digital components have opened up new spaces for drawing upon the cultural resources that students bring in to school. For instance, many Indigenous communities worldwide have strong heritage of craft practices connected to cultural identities, such as Cherokee basket weaving (Hill, 1997) or Navajo silversmithing in the United States, but these practices are often not incorporated into school-based learning. Wearable electronics technologies allow teachers and students to incorporate these community-based craft traditions and designs into school-based learning. The LilyPad Arduino kit for making wearable electronics combines a small, sewable computer (microcontroller) with a variety of sensors and actuators (Buechley, 2013) that are sewn together using a needle and special, conductive thread and then programmed on a computer (see Figure 2). The combination of high and low tech materials and practices involved in making electronic textiles (e-textiles) provides an ideal space for engaging diverse student voices.

The digital making context

During the 2013-2014 school year, an American Indian teacher and the eighty-six students (twelve to fourteen years old) who rotated through a junior high Native Studies class at a tribally controlled school in the Southwestern United States, participated in a three-week culturally responsive wearable electronic unit (Searle & Kafai, 2015). In partnership with the classroom teacher and the tribe's cultural resources department, students made and programmed light-up, hooded sweatshirts connected to their cultural heritage. Designs changed each quarter according to the following themes: (1) the elements (earth, wind, fire, water air), (2) desert plants, (3) animals, and (4) traditional foods. These projects not only allowed students to connect with community-based ways of knowing, such as the importance of relationships between humans and other inhabitants of an ecosystem, but also allowed them to critically address contemporary issues facing their community, such as a high occurrence of diabetes.

Data sources include daily field notes, student design drawings, photographs of students' in-process and completed artifacts, and final, reflective interviews with students and the classroom teacher. Data were coded using a two-step open coding process (Charmaz, 2000), allowing themes to emerge from the data and then be refined. Salient codes included design agency and the ability to learn from mistakes, home-school connections, and the difference between the e-textiles unit and other school-based learning environments.

Key observations and lessons

Students who participated in the Native Studies e-textile unit often referred to the process of making something with technology as “fun learning” that differed substantially from the kinds of passive activities they often completed at school. Justine, a seventh grade American Indian girl, had never sewn before but had watched her mom sew traditional clothing as part of her job with the tribe’s language and culture program. Although sewing was initially “really hard” for Justine, especially making sure that positive and negative lines of conductive thread did not cross, she grew to like the challenge and began spending her lunch periods getting extra help. After completing her design, she reported that she felt “amazing,” and she was especially proud of her family’s response to her finished, lighted sweatshirt. She described in an interview:

> I've shown the project to my family, well, the first time I showed it to them was last night and I was showing my brother. I was like, ‘Hey, you like my jacket?’ and he's like, ‘What the heck? What is that?’ I was like, ‘My jacket I made in second hour last quarter.’ He's like, ‘What?’ He's like, ‘Oh, DANG!’

In describing her family’s reaction to her project, Justine expressed tremendous pride in her ability to make something that incorporated her cultural background and technology, especially since the design Justine chose to make was an artistic interpretation of a plant that was considered sacred by her community.

Like Justine, Andrew, an American Indian boy who was in the eighth grade, created a lighted, hooded sweatshirt but, rather than a flower design, Andrew's design showed three raindrops that he programmed to light up as if they were falling. When you live in the desert, water is crucial for survival, and Andrew's design highlighted the importance of water to his tribe. For Andrew, the best part of the project was, "where we got to sew and make it light up" because he liked building things and because "connect[ing] all the stuff" [electronic components] was analogous to how people were connected to one another through a web of relationships.

(Insert Figure 2 about here.)

In these two brief examples, we see how American Indian students linked the design and production of wearable electronic technologies to their cultural backgrounds, not only by making culturally significant designs but also through the ways in which they were able to connect school-based learning about circuits and programming to home-based knowledge about craft, cultural traditions, and the importance of relationships with family members. Through these hybrid artifacts that combine tangible and digital elements, students were able to express not only their cultural backgrounds but also their unique voices as students capable of completing a complex, technological design challenge.

Concluding Thoughts

Research on student voice advocates for the transformative potential of incorporating youth's experiences and perspectives into educational programs. In particular, there is a focus on how the incorporation of students' voices can lead to feelings of agency, belonging, and competence (Mitra & Serriere, 2012). In this article, we explore two cases of how youth voice is included in and heard through engagement with digital technologies.

First, young English language learners participated in the design process of robot-based learning. From repeated user testing, it was clear that the children interacted autonomously making choices on their own (Gopnik, 2012) even when the designer gave specific, different instructions (e.g., the robot sensor problem). Their autonomous behavior changed the designer's choices, resulting in the production of more engaging robot/child interaction design (Hamre, et al., 2014). This illustrated that children were capable agents in the design of learning technology and contributed to the design through the transactional partnership with the designer (Tangen, 2008). Our dialogic design process incorporating children's autonomous response to on-going design enabled the children's voices to be heard.

In the second case, American Indian youth were charged with completing a series of design challenges with electronic textiles materials that connected back to heritage craft practices and key cultural ideas about the significance of certain plants and elements. Through the design of individual projects, students made their voices heard. Each completed, light up artifact identified in the hallways a student that was capable of school success. Further, by working on projects that were hands-on and portable, so that they could work on them at home, students helped create a transformative moment where teachers realized that certain kinds of projects grabbed students' attention more than others.

The two cases presented in this paper illustrated how new digital technologies can amplify student voice to provide learning experiences relevant to students' lives, especially for culturally and linguistically diverse students. Viewing youth as designers suggests a whole new paradigm: moving away from benevolent others (i.e., designers, educators, and policy makers) who develop programs for students, toward students being the key parties who produce the technological tools that work best for them. This vision might be the ultimate expression of student voice offered by digital technology: enabling youth to be digital makers and thereby managers of their digital worlds and also blurring boundaries between students' voices and the digital tools with which they engage.

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Figure 1. The robot and children's interaction snapshots.

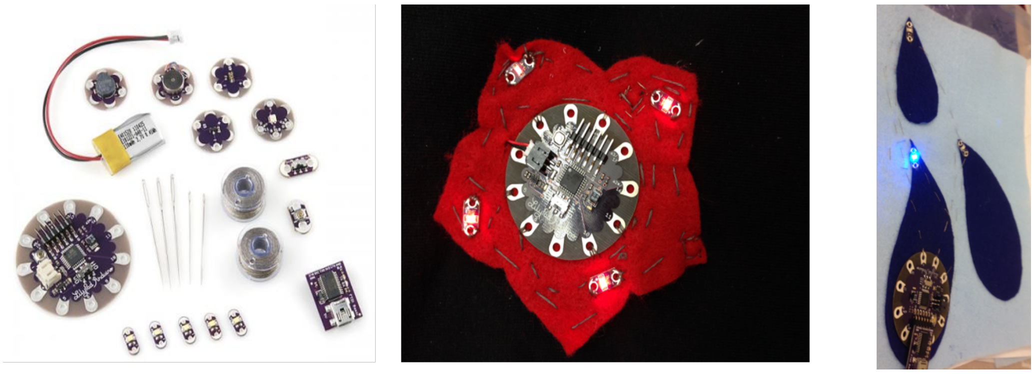

Figure 2. LilyPad Arduino construction kit, e-textiles by Justine and Andrew (left to right).