In this forum we celebrate research that helps to successfully bring the benefits of computing technologies to children, older adults, people with disabilities, and other populations that are often ignored in the design of mass-marketed products.

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Adding Reinforced Corners: Designing Interactive Technologies for Children with Disabilities

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There is growing global interest in designing technologies for children with disabilities, as evidenced by the recent workshop we organized on this topic at the annual Interaction Design and Children conference [1].

We recognize that in one sense, disability exists at an individual level, be it a temporary, degenerative, or permanent disability, occurring at birth or later in life. But while disability has a distinct medical basis that affects individuals, it is also shaped by cultural, societal, and familial norms. Impairments can be made more pronounced in some social situations, be a tremendous advantage in certain other environments, or make no difference at all. Disability is not an isolated issue, intersecting with age, gender, race, class, and geographic location. For example, formal schooling for a child with a disability in one country may involve local mainstream and special-needs schools, while in another region boarding schools may be the norm.

Taking this into account, how could we adapt Mitchel Resnick's popular metaphorical approach to designing children's creative thinking tools [2] to designing technologies for children with disabilities? Designers should equip such technologies, explain Resnick and colleagues, with the following three specifications: 1) *low floors* (easy to start, short learning curve for novices); 2) *high ceilings* (can accommodate increasingly complex projects); and 3) *wide walls* (many paths for self-expression, depending on a child's interests and passions).

Designers and researchers have primarily employed this framework to guide the building of children's computing environments and construction kits, such as Scratch or Programmable LEGO Bricks. In developing design principles, Resnick and Silverman considered "diversity of outcomes as an indicator of success" [2]. A successful system is one that is useful to a large number of diverse children. In thinking about designing technologies for children with disabilities, we use this framework to emphasize the diversity of *starting points* among children and their unique contexts, in addition to that of outcome. We also apply it to a set of technologies that work together, in addition to single technologies.

When employed as a design principle for technologies used by the heterogeneous, global population of children with disabilities (including mobility, sensory, cognitive, speech-language, and intellectual impairment), these goals take on nuanced meanings. To be an especially useful guide for those designing new technologies (which may blend no-, low-, and high-tech solutions) for children, adolescents, and teenagers with disabilities, we offer alternative

Photographs by Alannah Dsouza

▸ Photos of a project Dsouza, Barretto, and Raman are conducting at a boarding school for children with autism in Bangalore, India [7]. Top: A child sharing the music emitted by a touch-based multisensory toy with a researcher. Left: Children with autism collaboratively use a multisensory toy.

takes on Resnick et al.'s terms. We also add one additional specification: *reinforced corners*, for supporting the creative pursuits of children who may do best at the widest parts of the wall, the highest reaches of the ceiling, or at the ground floor, depending on the situation.

Low Floors with Ramps

For an interactive technology or learning environment to have a "low floor," children with relatively little experience should be able to learn the basics without extensive prior experience or knowledge.

However low a floor may be, without a "ramp" or other types of modifications, the entire system may be entirely out of reach for certain populations of children. Rahul Bhargava, a graduate student in the Lifelong Kindergarten Group at the MIT Media Lab, developed the Bricket as his master's thesis project, which adapted and extended the low floor of the Cricket programmable bricks for use by children who are blind or visually impaired [3]. While these children may have a great deal of expertise in using computers and other digital-assistive technologies to read or write, they rarely have the opportunity to build their own personally meaningful computational devices. Bhargava integrated tactile- and auditory-based interactions into the BricketLOGO programming system, effectively building a ramp for Cricket's low floor. Low floors are an even more important design consideration for children with disabilities, and are likely to be lower or need more thought.

Such ramps are not just about access to technology, but also about extending invitations for children with disabilities to participate alongside their peers, teachers, and families. Jenkins et al. describe the potential of a "participatory culture" to thrive in the current new media landscape [4]. A participatory culture is "a culture with relatively low barriers to artistic expression and civic engagement, strong support for creating and sharing one's creations, and some type of informal mentorship whereby what is known by the most experienced is passed along to novices."

Moreover, Jenkins et al. also identify a participation gap facing children growing up in the 21st century, or "the unequal access to the opportunities, experiences, skills, and knowledge that will prepare youth for full participation in the world of tomorrow" [4]. People with disabilities are largely under-represented in science and engineering fields [5]. The participation gap is detrimental not just to children with disabilities, but also to the larger world potentially denied access to the things these children know, the way they know them, and the things they may build with computational systems.

High Ceilings and Tall Ladders

Interactive technologies with "high ceilings" support a child's increasingly sophisticated projects. Systems with high ceilings have their drawbacks, though. Their many powerful, complex features may primarily get used only by a small group of experts who can devote the required time for lengthy training and have access to specialized materials and resources. The additional challenge of high ceilings is in providing expressive power for children with disabilities, who in many cases need very basic needs covered (e.g., basic communication).

To reach the highest ceilings, these children may require "tall ladders," or scaffolds that let every child progress at their own pace and excel to the best of their abilities. Peppler and Warschauer [6] discuss the case study of "Brandy," a nine-year-old girl, three years behind in school, with an IQ of 60 who had been diagnosed as having intellectual disabilities. Over the course of two and a half years, using Scratch as part of an afterschool Computer Clubhouse program in South Los Angeles, Brandy became a more confident and creative reader and writer through computer programming, despite low expectations by her peers and strong prejudices from her community. For Brandy, the diverse array of multimodal creative projects that are possible within Scratch's high ceilings allowed her to experiment with linking traditional and new literacy practices in increasingly complex ways that a more traditional curriculum could not. Brandy may have needed to spend more time on various rungs of the ladder (e.g., working independently at first only with the aid of Scratch cards), but she eventually created projects that outside evaluators commented were compelling, exemplary of youth production, and at a professional level. Children with disabilities have the capacity to do sophisticated work but may need specific adaptations.

Wide Walls and Frames of Interest

"Wide walls" are key to personalization and individuality in using a creative technology. They allow for as broad a range of creative possibilities as children's interests and passions are varied. For children with disabilities, the starting points and outcomes of creating and experiencing such interactive systems can be particularly diverse. The design principle of wide walls applies to children with disabilities in two main ways. First, wide walls can account for the wide range of variability within children with disabilities as a population or within specific disabilities. Secondly, an individual child with a disability such as autism spectrum disorder might favor deeply honing a highly specific area, or *frame of interest,* on that wall, instead of exploring the breadth of possibilities.

A challenge in designing for children with special needs is the wide variability within these populations. The same child might behave significantly differently based on the environment he or she is in or the medications he or she is taking. A child may learn very differently depending on the context (e.g., home, classroom, after school) and activity (e.g., therapy session, daily chores, communication, video gaming). Children with multiple disabilities may have additional, complex individual needs. Besides the use of the technology, this contextual variability also has implications for the research and development of these technologies. Accessing children with disabilities for the purposes of participatory design is particularly difficult because the population is relatively small.

Children with autism may have difficulty exploring the wide walls of interactive technologies because they usually favor repetitive play patterns with a few select toys. Alannah Dsouza, Maria Barretto, and Vijaya Raman are conducting research at a boarding school in Bangalore, India for children with autism, ages 5 to 11, evaluating the development, design, and impact of their Uncommon Sense toys project [7]. After observing the children's free play, arts and craft sessions, low-tech interactive activities, and experimentation with prototypes, the researchers developed a set of four tangible computing objects that must be used collaboratively (shared actions, movements, and voice) to trigger multisensory feedback (audio, visual, and tactile). The simple toys can be adapted to different settings, play partners, and activity sequences. The different play possibilities afforded by Uncommon Sense's wide—but not too wide—walls open up various key developmental skills, such as flexibility, turn taking, joint attention, and imitation.

Reinforced Corners

In addition to the three specifications above, we propose adding a fourth component, *reinforced corners*. At the points where the widest walls, lowest floors, or highest ceilings meet, exceptional children may need additional and unique types of support. For example, gifted students with disabilities ("mixed-need" or "twice-exceptional" students) are particularly at risk for growing frustrated or bored with existing interactive technologies because their needs—intellectual, social, physical, and emotional—are often not well understood or identified. Ample support and attention needs to be built into interactive technologies for the kids who push the boundaries of the walls, and who need additional opportunities at either the top of the ceiling or the lowest threshold of entry, depending on the environment.

Conclusion

Researchers and designers have primarily applied the "low floors, high ceilings, wide walls" approach to designing interactive technologies to mainstream computer-programming environments for kids such as Scratch and Programmable Bricks. When applied to the domain of children with disabilities, specific dimensions need to be taken into consideration: low floors with ramps (for participation), high ceilings and tall ladders (for expression), and wide walls and frames of interests (for personalization). A fourth specification—reinforced corners—should be considered for supporting exceptional children who may thrive at the corners where the widest walls, highest ceilings, and lowest floors intersect.

Children with disabilities are a richly diverse population. For example, two children of the same age, socioeconomic background, gender, and disability could need opposite design solutions. None of the authors has a disability (like the majority of people in the interaction design and technology fields), and we advocate for a more diverse community of scholars that includes increased opportunities for researchers and designers with disabilities themselves. One way to support this solidarity and community in mixed-ability spaces is to take into account the diverse lived experiences of young people with disabilities in the design of interactive technologies and computer-programming environments. Designing for children with disabilities is a bridge that runs two ways, as the potential knowledge exchange and shared experiences are mutually beneficial for all children and society at large.

ENDNOTES:

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