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.
— Juan Pablo Hourcade, Editor

The 3Cs for Preschool Children's Technology: Create, Connect, Communicate

Juan Pablo Hourcade, Luiza Superti Pantoja, Kyle Diederich, and **Liam Crawford,** University of Iowa
Glenda Revelle, Family Experience Design

A toddler using a smartphone or a tablet is not an unusual sight in high-income regions. In fact, today's preschoolers are the first generation growing up with interactive computing devices that are accessible to their cognitive and motor abilities, with some starting to use them as babies [1]. Prior to the wide availability of handheld touchscreen devices, the mouse and keyboard posed motor barriers to a significant portion of children under the age of four when using computers. In addition, the size and lesser mobility of desktops and laptops limited the practical use of computers for this age group. This barrier has now been lifted, but the research community has had difficulty keeping up with the rapid expansion of technology available to toddlers and preschoolers. Instead, there are thousands of commercial apps of varying quality available, and preschool children are using them without parents having a clear understanding of the benefits or potential risks.

It is too early to tell whether we should be concerned about this development. However, some of the uses of mobile devices by young children are not a particularly good fit with the type of activities associated with healthy development. They often involve socially isolating activities structured by apps, with a primary focus on the device, the experience of media, and engagement through instant gratification, with little in the way of personalization. The challenge is that such activities can get in the way of children experiencing healthy activities that involve being creative, connecting with the physical world, and communicating and engaging with others face-to-face.

This challenge comes with an opportunity for our community to make positive contributions to children's healthy development. If preschool children are going to use mobile apps, we might as well provide options that lead to healthy activities. To take advantage of this opportunity, inspired by evidence-based curricula and child-development theories, we propose a developmentally appropriate approach to technologies for this age group focused on the 3Cs: creating, connecting, and communicating. More specifically, technologies that follow the 3Cs approach are supportive of creative activities that connect children with their social and physical environment while emphasizing communication. Overall, the goal is to leverage children's interests to help them arrive at powerful ideas.

Insights

- Technologies following the 3Cs approach support creative activities that connect children with their social and physical environment, emphasizing communication.
- StoryCarnival uses the 3Cs approach to promote self-regulation by scaffolding make-believe play activities.
- Consider using the 3Cs approach to support learning processes.

INSPIRATION FOR THE 3CS APPROACH

The idea of the 3Cs comes in part from sociocultural approaches to child development, in particular, Lev Vygotsky's ideas on the social nature of learning. Vygotsky's views on development emphasize that children's development of skills and concepts occurs first socially (with help from others) and then individually [2]. One area he highlighted was the importance of make-believe play. Vygotsky's observation was that it leads to children regulating their behavior, in particular inhibiting actions that do not fit the make-believe context. This is due to children taking on roles with specific characteristics that bring about natural constraints within a motivating activity [2]. This self-regulation starts with physical behaviors and is followed by social behaviors, and then by cognitive processes such as attention [3].

Additionally, Vygotsky thought such play can help with the development of abstract thinking if children use generic props to represent different objects symbolically. According to the demands of role play, children can use and reuse the same props for different purposes. In other words, the props stand for something they are not, acting as symbols that represent something else. These concepts of play were incorporated into the successful Tools of the Mind curriculum. Tools of the Mind's make-believe activities also include play planning by children and the participation of adults as facilitators. Tools of the Mind has

strong evidence backing its approach, including large studies documenting children's improved executive function skills and academic performance when compared with those of children in standard preschool curricula [4].

Tools of the Mind's activities have a clear orientation toward children creating in a social context, connecting with their social and physical environment, and communicating with each other and adults through the stories they act out. These activities empower children, involve the participation of adults in a guiding role, and require planning and the delay of gratification. In addition, they link children's strong interests in stories and characters with powerful ideas in self-regulation, such as inhibitory control and task switching. We have the same vision for technology-supported learning ecologies for preschool children.

Seymour Papert's ideas on learning also influenced our approach. Papert, one of the parents of child-computer interaction, wanted children to be active, empowered learners who create items of interest in social settings. He thought such creative projects could leverage children's strong interests to allow them to arrive at powerful ideas [5]. In his support for these social, creative activities, Papert set the tone for our conceptualization of the 3Cs.

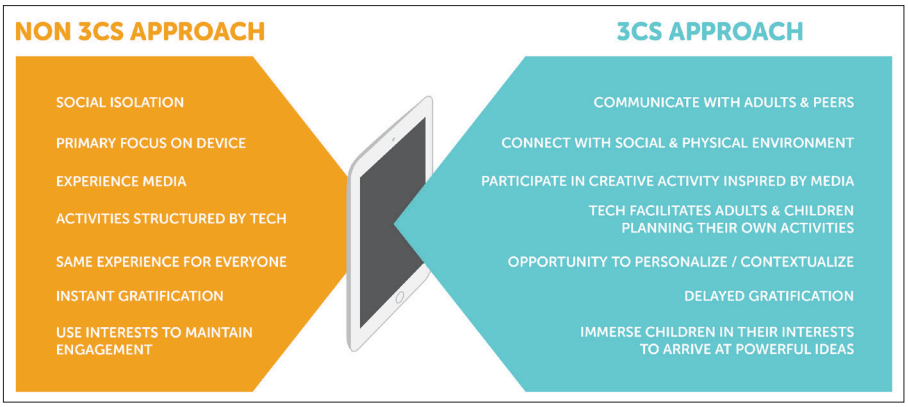
Vygotsky's and Papert's views are also compatible with systems approaches to child development. While researchers using systems approaches tend to focus on low-level changes in development, the theories also apply to high-level changes in skills, such as self-regulation. In particular, they emphasize the embodied nature of development, occurring through bidirectional interactions between the brain, the body, and the environment.

As children develop and learn, the brain, the body, and the environment change together.

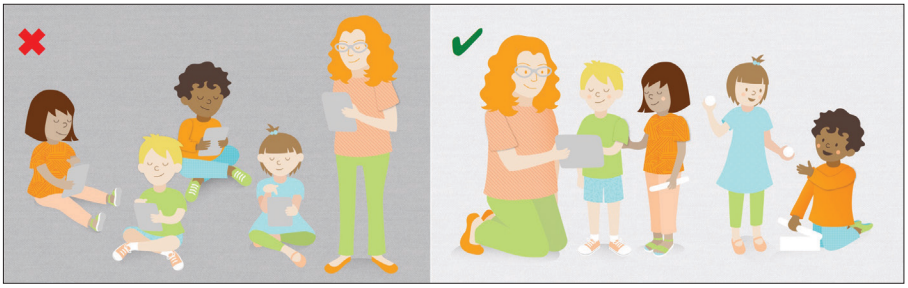
As children develop and learn, the brain, the body, and the environment change together [6]. The 3Cs approach takes into account this wider view of development through activities that involve social interaction and interactions with the physical environment, with the purpose of developing self-regulation.

To be consistent with these approaches to child development, we need to identify and design the most beneficial social and physical contexts in which children can develop. Technology-rich learning environments will be limited in their effectiveness for young children if they do not include activities that combine the use of technology with social interactions, communication, and interactions with the physical environment. Hence, in the 3Cs approach we use technology to scaffold, facilitate, and encourage creative activities that connect children with their physical and social environment, with an emphasis on communication. This approach increases the likelihood of beneficial

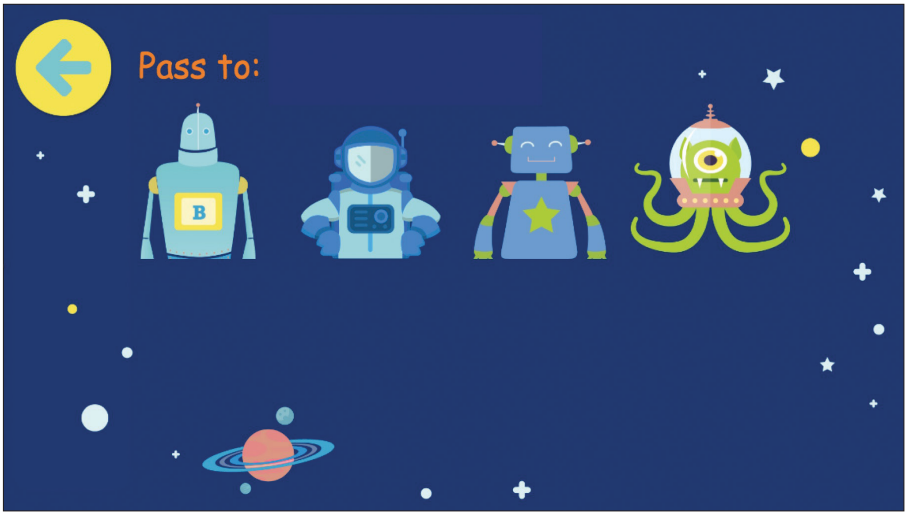
IMAGE BY TYLER OLSON



Non-3Cs vs. 3Cs technology activity characteristics.



On the left, a non-3Cs technology activity at a preschool. On the right, a 3Cs technology activity at a preschool.



Character-selection screen in StoryCarnival for a space-themed story.

developmental outcomes.

Then again, we may ask whether we need the digital realm at all. How exactly can technology help? We expect that computer technologies can provide value in several ways. First, computers can help bridge abstract and concrete thinking [5] and thus be a more accessible link to powerful ideas (e.g., helping with planning activities). Second, as very flexible tools, computers can more easily link children to their strong interests (e.g., through media) and enable them to create a wider array of entities that could be easily shared. Third, they can provide additional channels of communication. Fourth, they can provide scaffolds to beneficial activities, making it more likely that they will be adopted and enhancing them by providing appropriate supports.

CHALLENGES IN DEVELOPING 3CS TECHNOLOGIES

There are several challenges involved in designing and implementing 3Cs technologies for preschool children. These include developing child-centered design methods for this age group, integrating technology with the socio-physical environment, promoting creativity and communication, providing engaging support for adults, and maintaining children's engagement in delayed-gratification activities.

Identifying age-appropriate child-centered design methods is likely to be a challenge due to how quickly children's abilities change from age 3 to 4. Methods should adapt to a child's ability to communicate and to their social and creative skills, and should also incorporate caregivers. While it is tempting to rely on parents, teachers, and child-development experts to develop designs, we believe it is important to also include children in the design process as early and often as possible.

Integrating technology with the socio-physical environment is perhaps the greatest challenge in designing 3Cs technologies. At some point during a facilitated activity, the technology needs to yield focus to children's physical surroundings and to the people there. This may work in the form of having technology scaffold activities that do not involve technology. In fact, 3Cs apps could be designed specifically to get children to play without apps. Another possibility would be for 3Cs technologies to support connections with the socio-physical environment through sensors and actuators distributed in a physical space.

3Cs technologies should also promote creative activities and communication. The challenge is encouraging children to be authors and communicators instead of media consumers. Providing scaffolds to activities with creative and communicative aspects can help set the stage for more independence in both.

The engagement of teachers, parents, and other caregivers in 3Cs activities is crucial to their success, as these are not "babysitter" technologies. We need to inspire and motivate these caregivers and give them easily accessible guidance. Therefore, we must study how to design and deliver engaging advice and support for adults.

The 3Cs approach also involves delayed gratification that is gained through the creative, social activities. The challenge is to get children engaged in such activities even though they may be used to instant gratification when they use technologies. We expect that one useful strategy is to design activities that immerse children in their strong interests.

STORYCARNIVAL: A 3CS TECHNOLOGY

For the past few months, we have been iteratively developing a 3Cs technology for 3- to 4-year-old children called StoryCarnival, with the goal of helping children develop self-regulation skills. StoryCarnival takes inspiration from the make-believe play activities in Tools of the Mind, and from Papert's example of Brazil's *escolas de samba* (samba schools) as matching his vision of learning in society [5]. Brazil's escolas de samba traditionally participated in a 3Cs process involving storytelling, planning, and performance that engaged the strong interests of people at various skill levels to arrive at powerful ideas, which in turn led to spectacular Carnival parades.

StoryCarnival helps children and their caregivers get inspiration for and plan make-believe play through a Web-based app. The components we are developing include:

- interactive stories to introduce themes and set the stage for collaborative play;
- a play planner that helps children and caregivers select a theme and roles, and set up the use of the physical environment (including generic physical props);
- guidance for caregiver participation; and
- support for contextualization and personalization through the ability to edit and create new interactive stories.

A typical use of StoryCarnival would involve a group of children experiencing an interactive story that introduces a theme and characters. This would be followed by use of the play planner to guide children through negotiating which character each of them will play, and how they will make use of the physical space and props. Once the make-believe play starts, the app moves to the background and children focus on playing with each other, in the physical space, using generic props with no electronics, with guidance from a caregiver.

In our deployment of prototypes at a local preschool, we have observed that StoryCarnival prompts the type of behaviors targeted by Tools of the Mind, including the use of generic props to represent different objects, children staying in role, children explicitly switching roles, and continuing stories from previous play sessions. Our hope is that a successful development of StoryCarnival can deliver many of the benefits of curricula such as Tools of the Mind in a more accessible manner. Similar approaches could make other evidence-based activities easier to implement.

3CS ELSEWHERE?

As we developed the 3Cs concept, we realized that our participatory design activities in the design of StoryCarnival, as well as those used in many other projects, were 3Cs activities too. Most user-centered design activities involve creating (designs, prototypes); connecting with users, stakeholders, and their context; and communicating with all involved parties. It makes sense that design processes benefit from a 3Cs approach, as they are also learning processes.

With that in mind, should we apply the 3Cs approach to other situations? Are there other learning processes that could benefit from a 3Cs approach? How about other technology-driven activities? It is certainly not only children who look like they are isolated from their social and physical environment when using technologies. While there is nothing wrong with individually experiencing a reasonable amount of very engaging, gratifying media, we could do better in providing a more balanced set of experiences with technologies. Do you have a balance of non-3Cs and 3Cs experiences when using technology? How about when you are not using technology?

As you consider these questions, we will continue pursuing 3Cs approaches in the design of technologies for young children, with the hope that they grow up to be creative adults with strong connections to their social and physical environment and fluid communication skills.

Endnotes

1. Hourcade, J.P., Mascher, S., Wu, D., and Pantoja, L. Look, my baby is using an iPad! An analysis of YouTube videos of infants and toddlers using tablets. *Proc. of the 33rd Annual ACM Conference on Human Factors in Computing Systems*. ACM, New York, 2015, 1915–1924.
2. Vygotsky, L.S. Play and its role in the mental development of the child. *Soviet Psychology 5*, 3 (1967), 6–18.
3. Bodrova, E. and Leong, D.J. *Tools of the Mind*. Pearson, 2007.
4. Blair, C. and Raver, C.C. Closing the achievement gap through modification of neurocognitive and neuroendocrine function: Results from a cluster randomized controlled trial of an innovative approach to the education of children in kndergarten. *PLoS ONE 9*, 11 (2014), e112393; https://doi.org/10.1371/journal.pone.0112393
5. Papert, S. *Mindstorms: Children, Computers, and Powerful Ideas*. Basic Books, 1980.
6. Spencer, J.P., Perone, S., and Buss, A.T. Twenty years and going strong: A dynamic systems revolution in motor and cognitive development. *Child Development Perspectives 5*, 4 (2011), 260–266; https://doi.org/10.1111/j.1750-8606.2011.00194.x

Juan Pablo Hourcade is an associate professor in the University of Iowa's Department of Computer Science.
→ juanpablo-hourcade@uiowa.edu

Luiza Superti Pantoja is an informatics Ph.D. student at the University of Iowa.
→ luiza-supertipantoja@uiowa.edu

Kyle Diederich is a computer science Ph.D. student at the University of Iowa.
→ kyle-diederich@uiowa.edu

Liam Crawford is a computer science undergraduate student at the University of Iowa.
→ liam-crawford@uiowa.edu

Glenda Revelle is the president of Family Experience Design.
→ revelleg@gmail.com

DOI: 10.1145/3096461