EDC | Learning transforms lives.

# Early STEM Learning and the Roles of Technologies

Shelley Pasnik and Naomi Hupert

Education Development Center, Inc.

Education Development Center, Inc. designs, implements, and evaluates programs to improve education, health, and economic opportunity worldwide. For more information, visit edc.org.

## Developing Children's Sense of Wonder about Their World

From birth to age eight, children take their first steps into a lifelong journey of learning, exploring, and questioning. The journey begins with a child's early encounters with people and objects, and rapidly expands to encompass a community that extends well beyond family and home. While every child's early learning experiences are unique, many important experiences are not universal. The skill gap that emerges and grows exponentially during children's first years of schooling exposes these inequities in experience, and is particularly evident in science, technology, engineering, and mathematics (STEM) content areas where economically disadvantaged children are substantially outperformed by their peers.

The education, research, and policy communities have begun to direct attention and resources towards this problem, but many questions persist regarding how best to change the current direction of early STEM learning in this country. How will early learning educators be prepared to teach STEM topics in developmentally appropriate ways? What kinds of resources should they have access to? What role can parents and other family members play in supporting the STEM engagement of young children? The potential for technological tools (software and apps, for example) is often called out as a cost-effective way to address some of the questions and challenges that are identified by educators and others. Technology can offer access to content for adults and can provide children with information as well as interactive opportunities, and can be accessed in homes, schools ,and other locations where extended families or peers may be included in digital activities. While many of these possibilities for technology are realistic, they also require substantial planning and support to be effective and to be relevant to the lives of young children and the families and communities within which they live, play, and learn.

## How Technology Can Make a Difference

Digital resources, such as narrative-rich videos, mobile apps, and online games with built-in assessments, can play productive roles in preschool teaching and learning, but they require thoughtful integration. Technology tools, even the best-designed ones, can never replace human interaction or good teaching. Children, especially young children, need caring and knowledgeable adults to help them navigate and learn about the world, and this includes the world of technology.

Digital tools can provide access to information that is otherwise invisible: how seeds sprout roots and grow into plants; how shadows shift as the sun passes overhead; or how wind patterns move storms across the globe. They also can provide models to children and adults about how to ask questions about the world in which we live, and can provide guidance to adults on how to help children conduct experiments, ask questions that can be tested, and provide explanations for phenomena based on the data they collect through their own experiments and through observations of others.

Technology can model approaches to learning, ways of interacting with peers, adults or children, and most importantly, it can model through visual and audio information how adults and children can engage in meaningful discourse about science and the world around them. In addition, technology can be a tool for educators to use for their own learning, providing access to resources, professional development and to examples of how developmentally appropriate STEM concepts and activities can be introduced to children in ways that will expand their sphere of experience.

In our decades of experiences as researchers, developers, and providers of professional development, we have found that early STEM learning and teaching can be enhanced if technology is used to:

- **Provide models** of real engagement for educators, parents, and children.

- **Connect educators** to a community of fellow learners (e.g. provide access to professional development opportunities that support STEM content and skills that are appropriate for early learning settings).

- **Provide ready access** to teacher training resources, such as teaching guides and adaptable student activities, using a variety of modalities.

- **Expose children and adults** to phenomena and visual and auditory information that they might not otherwise have access to, such as observing things that may not be readily observable in the classroom and recording/reviewing "data.""

- **Promote opportunities** for children to develop early science skills/practices.

- **Engage children in tasks using technology** that invite sharing, collaborating, and discussing, such as paired playing of digital games.

- **Provide tailored learning opportunities** that reflect an educator's level of prior knowledge or experience.

- **Promote social interactions** and joint engagement between children and with adults.

- **Support the roles and responsibilities of parents and caregivers** in supporting integrated, hybrid hands-on learning that goes beyond technology but incorporates technology. Adults can support inquiry-based experiences, incorporating both advanced vocabulary and open-ended questions that have been correlated with improved early literacy scores.

It is important to note that there is a growing body of evidence that a 1:1 device-to-child approach is not the way to support young children's learning (Blackwell, Lauricella, Wartella, Robb, & Schomburg, 2013). Instead, technologies, such as touchscreen tablets, are best integrated when children use them in pairs or small groups, which is consistent with a learning-centers structure (e.g., a small set of Chromebooks serves as a learning center in the way that a block corner and a water table is a learning center).



## Teachers Are Essential to Supporting Early STEM Learning

Teachers are crucial to young children's learning. Unfortunately, research shows that many early childhood teachers are not well prepared to teach STEM to young children in developmentally appropriate ways: they lack an adequate grounding in relevant STEM knowledge, and in pedagogical strategies that support the learning of that knowledge, they lack access to professional development opportunities in STEM (Brenneman, 2010), and they lack access to high-quality resources that can help all students achieve standards-based STEM learning outcomes in a rapidly changing educational landscape (Tu, 2006).  In addition, many adults, including educators, underestimate what young children are capable of learning, and therefore may not provide many opportunities for children to make sense of numbers, patterns, and relationships, or to interact with the scientific phenomena or practices that set the stage for later STEM learning.

Teachers need resources that offer relevant, developmentally appropriate content, support their understanding of STEM within early learning settings, and provide them with models of how to engage young learners in STEM experiences that can lay a foundation for later successful STEM learning. Families also need resources that build their knowledge in these key areas of early learning. Well-planned and structured uses of technology—both as instructional support for children and as a learning and modeling tool for educators and other adults spending time with young children—can help address these needs.

Study findings indicate that models provided by digital media can result in gains in educators' and parents' understanding of the kinds of math activities appropriate for young children; their understanding of how to engage children in math activities in non-school environments; and their degree of comfort in supporting children with math activities (Pasnik & Llorente, 2013). When technology is designed with both children and adults in mind, and with careful attention paid to learning content, adults and children can both benefit. However, these outcomes are only possible when technology is implemented in ways that build on what we know about young children and about the adults who work and care for them.

Because teachers are essential to any early learning environment, the development of digital resources for early learners must be structured to:

- **Acknowledge the crucial role teachers play** as mediators of digital experiences (e.g., providing guidance for adults about a particular resource, or learning goal, so that it can be reinforced by an adult during off-line discussion and activities).

- **Recognize and integrate the needs of adults, as well as children,** into content (e.g., integrating models of dialogue between adults and children in ways that call out specific aspects such as asking clarifying questions or re-stating an opinion).

- **Provide resources that help teachers interpret and apply** educational standards that reflect our growing understanding of what children are capable of learning. For example, in Chicago, EDC is providing professional development to general education and special education teachers in grades K–5 to significantly increase their capacity to help all students achieve standards-based learning outcomes in mathematics. In Massachusetts, we are working with teachers across the state to integrate computational thinking into science and mathematics learning in grades 1–6.

- **Support early learning and elementary school teachers** with STEM pedagogy and content knowledge through professional development opportunities that fit the unique needs of early learning professionals.

- **Continue to develop and study models of research-practice collaboration** to improve student learning of STEM in the early grades using interactive mobile technologies.

To support early childhood educators, it is important to understand their unique needs and the contexts in which they work. For example, early childhood educators working in lower-income communities often lack financial resources to cover costs for professional development (Bueno,

Darling-Hammond, & Gonzales, 2010), and nearly half score at the lowest levels of proficiency on adult literacy measures (Kaestle, Campbell, Finn, Johnson, & Mikulecky, 2001). Effective professional development models that are disseminated via digital media, draw on visual and auditory presentation of information, and can be accessed asynchronously may support this population of teachers more fully than traditional professional development efforts.



## The Need to Support STEM Learning for *ALL* Children

The digital divide in STEM is just one piece of the broader divide in opportunity among the nation's children. With 45% of children in the United States living in homes that are low income (Jiang, Jiang, Ekono, & Skinner, 2016), the lack of access to the kinds of resources that might support exposure to STEM-related content is widespread and pervasive.

Our country's current policies and limited programs support this divide in multiple ways:

- **High-quality preschool is unavailable for large numbers of families** across the country, with only 29% of 4 year olds enrolled in a prekindergarten program (NIEER, 2016).

- **When children have access to preschool programs, they are unlikely to engage in science learning,** and have fewer opportunities to learn science and math than other

readiness skills, such as language and literacy, during their preschool day (Brenneman, Stevenson-Boyd, & Frede, 2009; Early et al., 2010; Greenfield et al., 2009).

- **Early childhood educators need support to foster early STEM learning**—as noted above, early childhood educators lack access to instructional resources designed for early learners in science (NAEYC, 2002) and often have minimal or no access to pre-service and in-service instruction or professional development to support the teaching and learning of science (Brenneman, 2010).

Educators, researchers, and policy makers who spend time in early learning settings see these challenges played out on a daily basis and recognize that they are all tied to a single driving need to provide high-quality early learning experiences to every child. In order to do this, we must build school-home-community partnerships that give all children the opportunity to engage in authentic scientific explorations and mathematical thinking, both as areas of study in their own right, and as components in a holistic approach to children learning which does not segregate experience into content area.

As educators, we must create spaces where children can experience STEM in the arts, in reading, and in the community. This includes exposing all children to the concepts, vocabulary, and experiences that accompany strong and developmentally appropriate STEM activities and preparing their teachers to support this endeavour. Technology can support this goal, but only with considerable effort to ensure that widespread access is a reality, and that high-quality content that aligns with learning goals and children's developmental trajectories is consistently available.

## Considerations for Strengthening Early STEM Learning

In addition to the early STEM teaching and learning recommendations we list above, below is a broader set of considerations that grow out of our organization's decades of work at local, state and federal levels:

- **Make high-quality early learning synonymous with high-quality early STEM learning.** Good early learning is STEM learning; they should not be separated or isolated. Children experience the world as a whole, and early childhood educational experiences should not force that whole into isolated pieces. Instead we should build on the opportunities that technology can offer to support an inclusive approach to STEM across all fields including the arts, literacy, and social studies. And we should use technology to contribute to children's language and vocabulary development across all fields by providing strong models and contexts for language use that reaches children and the adults in their lives.

- **Create cohesion and consistency at the federal level.** The Office of Special Education Programs, the National Science Foundation, the Administration for Children and Families, as well as programs authorized under the Every Student Succeeds Act, each have specific priorities related to young children and STEM. Moving forward, it will be important for federal agencies to have a coherent frame that supports the appropriate use of technology to support young children's learning rather than taking separate, or worse, fragmented approaches.

- **Draw from strong, existing models of early STEM teaching and learning, including the high-profile Ready To Learn program and innovative R&D grants.** Much of our current work emphasizes the role that adults play in mediating young children's use of digital games and videos, as well as in supporting children's hands-on investigations of STEM in developmentally appropriate ways. We try to reflect this approach to technology in our research, and also in any kind of guidance we provide to educators. Through the U.S. Department of Education's Ready To Learn Program and a $15 million program of research, for example, we have the opportunity to help PBS and the Corporation for Public Broadcasting create better services for young children and their families, especially in communities where there are high concentrations of poverty (Pasnik, Llorente, Hupert & Moorthy, 2016).

  Likewise, with National Science Foundation and U.S. Department of Education grants, and with funding from private foundations such as Heising-Simons Foundation, we are identifying developmentally appropriate strategies and tools for using technology and media to support STEM learning among children in low-income communities that historically have had less support for early engagement with STEM content and practices. Along with SRI International and WGBH, we are working in formal and informal settings in partnership with researchers, media producers, and educators who are using iterative co-design processes to inform the development of evidence-based curricular programs and professional development resources (Orr, 2016).

- **Move the conversation away from screentime and toward quality STEM learning with technology.** The amount of time young children spend with technology is well documented (Rideout & Saphir, 2013). It is important to change the conversation about whether children should have screen time to instead focusing on the importance of providing young children with equal opportunities to have access to high-quality educational technologies that support STEM learning.

- **Commit to equity completely.** As early as kindergarten, there are painfully real achievement gaps between white and minority children and between children from higher- and low-income households, but we need not accept these gaps as inevitable. Our organization has a special focus on meeting the needs of children from disadvantaged communities and children who are dual language learners, on engaging and supporting families, and on building the capacity of educators and communities to sustain improvements. A federal i3 development grant, for example, has given us the opportunity to use the engaging context of science to support the literacy and academic success of young English language learners. Working with Hartford Public Schools and the Connecticut Science Center, we are providing 100 pre-K and first-grade teachers and coaches with professional development, and engaging 2,000 families in their children's early science and literacy learning through classroom explorations, family events, and family "toolkits" to extend science exploration at home.

## References

Blackwell, C. K., Lauricella, A. R., Wartella, E., Robb, M., & Schomburg, R. (2013). Adoption and use of technology in early education: The interplay of extrinsic barriers and teacher attitudes. *Computers & Education, 69*, 310–319.

Brenneman, K. (2010). P*lanned Explorations and Spontaneous Discoveries: Supporting Scientific Inquiry in Preschool*. Austin, TX: DML Summer Institute.

Brenneman, K., Stevenson-Boyd, J., & Frede, E. C. (2009). Math and science in preschool: Policies and practice. *Preschool Policy Brief, 19*. New Brunswick, NJ: National Institute for Early Education Research.

Bueno, M., Darling-Hammond, L., & Gonzales, D. (2010). *A matter of degrees: Preparing teachers for the pre-k classroom. Pre[k] now: A campaign of the Pew Center on the States*. Washington, DC: The Pew Center on the States.

Clarke Brown, K. (2015). *Using technology in early childhood classrooms*. New Brunswick, NJ: Center on Enhancing Early Learning Outcomes.

Early, D. M., Iruka, I. U., Ritchie, S., Barbarin, O. A., Winn, D. C., Crawford, G. M., & Pianta, R. C. (2010). How do pre-kindergartners spend their time? Gender, ethnicity, and income as predictors of experiences in pre-kindergarten classrooms. E*arly Childhood Research Quarterly, 25*, 177-193.

Greenfield, D. B., Jirout, J., Dominguez, X., Greenberg, A., Maier, M., & Fuccillo, J. (2009). Science in the

preschool program: A programmatic research agenda to improve school readiness. *Early Education and Development, 20*(2), 238–264.

Jiang, Y., Ekono, M., & Skinner, C. (2016). B*asic facts about low-Income children: Children under 18 years, 2014*. New York: National Center for Children in Poverty, Mailman School of Public Health, Columbia University.

Kaestle, C. F., Campbell, A., Finn, J. D., Johnson, S. T., & Mikulecky, L. J. (2001). *Adult literacy and education in America* (NCES 2001-534) Issue 4, p. 67

Kallery, M., & Psillos, D. (2001). Preschool teachers content knowledge in science: Their understanding of elementary science concepts and of issues raised by children's questions. *International Journal of Early Years Education, 9*(3), 165-179.

National Association for the Education of Young Children (NAEYC) and National Association of Early Childhood Specialists in State Department of Education (NAECS/SDE). (2002). E*arly learning standards: Creating the conditions for success*. Washington, DC: Authors.

National Institute for Early Education Research. (2016). *The State of Preschool Yearbook 2015*. New Jersey: Rutgers University.

Orr, J. (2016). *Early Math with Gracie & Friends*. Boston: WGBH.

Pasnik, S., & Llorente, C. (2013). *Preschool teachers can use a PBS KIDS transmedia curriculum supplement to support young children's mathematics learning: Results of a randomized controlled trial*. New York, NY, & Menlo Park, CA: Education Development Center, Inc., & SRI International.

Pasnik, S., Llorente, C., Hupert, N., & Moorthy, S. (2016). *Reflections on the Ready To Learn Initiative, 2010 to 2015: How a Federal Program in Partnership with Public Media Supported Young Children's Equitable Learning During a Time of Great Change.* New York, NY, & Menlo Park, CA: Education Development Center, Inc., & SRI International.

Rideout, V. J., & Saphir, M. (2013). *Zero to eight: Children's media use in America 2013*. San Francisco, CA: Common Sense Media.

Tu, T. (2006). Preschool science environment: What is available in a preschool classroom. Early Childhood Education Journal 33, 245–251.