**Spatial Skills: A Neglected Dimension of Early STEM Education**

By [**Jill Berkowicz and Ann Myers**](http://blogs.edweek.org/edweek/leadership_360/) on February 16, 2017 7:02 AM |



***We welcome guest bloggers Tamara Toub, Postdoctoral Fellow, Temple University; Kathy Hirsh-Pasek, Professor of Psychology, Temple University and  Senior Fellow Brookings Institution; Roberta Michnick Golinkoff, Professor of Education, University of Delaware.***

[**A new report**](http://www.joanganzcooneycenter.org/publication/stem-starts-early/) ("STEM starts early: Grounding science, technology, engineering, and math education in early childhood") by the [**Joan Ganz Cooney Center at Sesame Workshop**](http://www.joanganzcooneycenter.org/) and [**New America**](https://www.newamerica.org/) provides intriguing insights into the current state of STEM learning (Science, Technology, Engineering and Mathematics) in early childhood.  Lead author Elisabeth R. McClure and her colleagues did an excellent job describing the importance of STEM development by culling together information not only from scientific literature but also from conversations with researchers, policy makers, and practitioners.  The report emphasizes that STEM fields rely on more than just knowledge of facts like 4 + 2= 6, that tomatoes are really fruits, or how to operate computers. No, STEM success relies on broader abilities, such as strong reasoning and problem-solving skills.

The main focus of the report is on barriers to early STEM learning, with clear suggestions on how to overcome those barriers.  Yet, the attempt to write a broad and far reaching analysis of the field gave short shrift to an emerging giant in this field - the development of spatial skills. Mounting empirical evidence suggests that spatial skills actually predict success in STEM fields out to adulthood (Newcombe, 2010; Uttal, Miller, & Newcombe, 2013; Wai, Lubinski, & Benbow, 2009).  Indeed, they may serve as a STEM "gateway" (Uttal & Cohen, 2012).  Despite the evidence, however, the importance of spatial skills is often overlooked as a key feature of STEM education.  This frequent neglect of spatial development creates an additional barrier to children's STEM learning.

Several pieces of data cement why an emphasis on spatial skills is critical to any comprehensive discussion of STEM.  For example, preschoolers who do worse in tests of spatial ability at age 3 have lower math readiness scores at age 5 (Verdine, Golinkoff, Hirsh-Pasek, & Newcombe, 2017). Early spatial skills along with "executive function" skills (working memory, attention, flexibility, and planning) account for over *70%* of children's math scores when they stand on the doorstep of formal schooling (Verdine, Irwin, Golinkoff, & Hirsh-Pasek, 2014).  And, though many people know that there is a gaping divide between low- and middle-income 3-year-olds in the vocabulary that they hear and use, there exists a large but lesser known spatial gap between these groups of children, too (Verdine, Irwin, et al., 2014).

Whether it is in knowing shape names like *circle* or *rectangle*, using spatial language like *around* and *between*, or simply copying a block design, spatial experiences vary widely among young children, and these experiences contribute to a robust foundation for STEM success.

Thankfully, it is not difficult to draw out the relevance of spatial skills in the conversation about early STEM development.  Further, there is much evidence to suggest that it is easy to foster early spatial learning as a core component of early preschool programs -- a notion highlighted in [**a news story**](https://ww2.kqed.org/mindshift/2017/01/29/why-spatial-reasoning-is-crucial-for-early-math-education/?utm_source=facebook.com&utm_medium=social&utm_campaign=npr&utm_term=nprnews&utm_content=20170203) published just days before the report from the Cooney Center and New America was released.  Here, we briefly outline additions to the report's 5 major findings to highlight the ways in which spatial development directly relates to their broader early STEM discussion:

**Finding 1: "Both parents and teachers appear to be enthusiastic and capable of supporting early STEM learning; however, they require additional knowledge and support to do so effectively."** (pg.5)

Parents and teachers need a solid understanding of what spatial skills are. Spatial skills involve the mental manipulation of information about objects in the environment (Uttal, Meadow, et al., 2013). As adults, we use these skills a lot - when we navigate city streets, follow instructional diagrams to put together do-it-yourself furniture, pack an apartment's worth of belongings into a small moving truck, and so forth.  Even young children tap into spatial skills as they navigate by crawling or toddling around a room and (generally) avoid bumping into furniture.  While spatialmistakes like making a wrong turn are no big deal, others can have serious consequences.  Consider the ramifications of poorly installing a child's car seat or the consequences of spatial errors by professional architects and builders, air traffic controllers, or surgeons.  Helping stakeholders to recognize spatial experiences and their importance will facilitate the incorporation of spatial skills into STEM support efforts.

**Finding 2: "Teachers in early childhood environments need more robust training and professional development to effectively engage young children in developmentally appropriate STEM learning."** (pg. 6)

Teachers need a better understanding of the development of spatial skills.  Many people believe that there is nothing we can do about someone having poor spatial skills; however, an accumulation of evidence has demonstrated that spatial skills can be improved (Uttal, Meadow, et al., 2013).  Toys like shape sorters, block sets, and puzzles inherently invite spatial thinking, and adults can support STEM learning by joining in these playful activities (Verdine, Golinkoff, Hirsh-Pasek, & Newcombe, 2014).  Indeed, adults provide additional support during such activities by using spatial language to label spatial concepts for children (Pruden, Levine, & Huttenlocher, 2011) and by encouraging children to think critically about topics like the defining characteristics of shapes (Resnick, Verdine, Golinkoff, & Hirsh-Pasek, 2016).  Spatial learning opportunities are already occurring in children's lives; it's a matter of increasing teachers' recognition and use of these opportunities for children's STEM development.

**Finding 3: "Parents and technology help connect school, home, and other learning environments like libraries and museums to support early STEM learning."** (pg. 6)

Activities like block-building or paper-folding are often found both at home and at school.  Children's museums can also incorporate spatial construction and related skills, and some have already begun to do this with exhibits like The Children's Museum of New Hampshire's [**Rigamajig**](http://rigamajig.com/), [**Boston Children's Museum's Construction Zone**](http://www.bostonchildrensmuseum.org/exhibits-programs/exhibits/construction-zone), the [**Please Touch Museum's Imagination Playground**](http://www.pleasetouchmuseum.org/experience/permanent-exhibits/), and the [**Exploratorium's Tinkering Gallery**](https://www.exploratorium.edu/visit/south-gallery).

There are also some emerging technologies that offer intriguing juxtapositions of digital and concrete worlds. Virtual reality experiences, for example, or the [**Osmo**](https://www.playosmo.com/en/) game system that invites children to manipulate objects in front of an iPad camera to affect their gameplay on the screen. Our research with colleagues (Zosh et al., 2015) suggests that some digital spatial toys might not be as good as their traditional, non-digital counterparts: parents used more spatial language when their 2-year-olds manipulated a traditional shape sorter than when the toddlers played with an electronic version.  The digital toy got in the way! Parents spoke less about the shapes and more about things like button-pushing.  But the jury is largely out in this area, and in [**our own current research**](https://ies.ed.gov/funding/grantsearch/details.asp?ID=1543) we are investigating the effectiveness of early spatial training with objects on a touchscreen versus similar training with real objects on a tabletop.  This and other research will further inform efforts to leverage technology to promote children's spatial learning experiences.

**Finding 4: "Research and public policies play a critical role in the presence and quality of STEM learning in young children's lives, and both benefit from sustained dialogue with one another and with teachers in the classroom."** (pg. 6)

Although spatial skills can sometimes slip through the cracks, attention to them has been growing.  The increased emphasis on early spatial skills is reflected in initiatives like the [**Common Core Standards**](http://www.corestandards.org/Math/Content/G/), which has a geometry section that incorporates many spatial concepts.  Research articles have emerged on relationships between early spatial skills and mathematics skills (Verdine et al., in press), potential effects of spatial training on spatial and mathematics development (Hawes, Moss, Caswell, & Poliszczuk, 2015; Levine, Ratliff, Huttenlocher, & Cannon, 2012; Verdine, Irwin, et al., 2014), and the incorporation of spatial training into early education curricula, such as *Building Blocks* (Clements & Sarama, 2008).

**Finding 5: "An empirically-tested, strategic communications effort is needed to convey an accurate understanding of developmental science to the public, leading to support for meaningful policy change around early STEM learning."** (pg. 7)

The report incorporated [**research by the FrameWorks Institute**](http://www.joanganzcooneycenter.org/2017/02/06/a-stem-story-for-early-stem-learning/) identifying effective ways to educate the public about STEM.  Given common misconceptions about both the importance of spatial skills and the degree to which we can improve these skills, we similarly need to provide clarifications and heighten the public's appreciation for the early importance of spatial skills.  With such efforts, we can move forward collectively and productively to enable our children to achieve the STEM skills they will need for success.

**Thus, explicit emphasis on spatial skills is highly compatible with the arguments made in the original report and contributes to the evidence-based suggestions for improved STEM learning.  To that end, we propose adding a 6th finding:**

***Finding 6:*** *Discussions about STEM learning need to incorporate spatial skills more explicitly and recognize the substantial role these skills play in children's STEM development.  We must increase awareness of what spatial skills involve, their relevance to everyday life and STEM success, and how we can support young children's spatial development as part of our improvements in STEM education.*

This friendly amendment to the report encourages families, educators, and policymakers to make spatial skills a key part of all discussions of early STEM development.

**References** Clements, D. H., & Sarama, J. (2008). Experimental evaluation of the effects of a research-based preschool mathematics curriculum. American Educational Research Journal, 45(2), 443-494. https://doi.org/10.3102/0002831207312908

Hawes, Z., Moss, J., Caswell, B., & Poliszczuk, D. (2015). Effects of mental rotation training on children's spatial and mathematics performance: A randomized controlled study. Trends in Neuroscience and Education, 4(3), 60-68. https://doi.org/10.1016/j.tine.2015.05.001

Levine, S. C., Ratliff, K. R., Huttenlocher, J., & Cannon, J. (2012). Early puzzle play: A predictor of preschoolers' spatial transformation skill. Developmental Psychology, 48(2), 530-542. https://doi.org/10.1037/a0025913

Newcombe, N. S. (2010). Picture this: Increasing math and science learning by improving spatial thinking. American Educator, 34(2), 29.

Pruden, S. M., Levine, S. C., & Huttenlocher, J. (2011). Children's spatial thinking: Does talk about the spatial world matter? Developmental Science, 14(6), 1417-1430. https://doi.org/10.1111/j.1467-7687.2011.01088.x

Resnick, I., Verdine, B. N., Golinkoff, R. M., & Hirsh-Pasek, K. (2016). Geometric toys in the attic?  A corpus analysis of early exposure to geometric shapes. Early Childhood Research Quarterly, 36, 358-365. https://doi.org/10.1016/j.ecresq.2016.01.007

Uttal, D. H., & Cohen, C. A. (2012). Spatial thinking and STEM education. In Psychology of Learning and Motivation (Vol. 57, pp. 147-181). Elsevier. Retrieved from http://linkinghub.elsevier.com/retrieve/pii/B9780123942937000042

Uttal, D. H., Meadow, N. G., Tipton, E., Hand, L. L., Alden, A. R., Warren, C., & Newcombe, N. S. (2013). The malleability of spatial skills: A meta-analysis of training studies. Psychological Bulletin, 139(2), 352-402. https://doi.org/10.1037/a0028446

Uttal, D. H., Miller, D. I., & Newcombe, N. S. (2013). Exploring and enhancing spatial thinking: Links to achievement in science, technology, engineering, and mathematics? Current Directions in Psychological Science, 22(5), 367-373. https://doi.org/10.1177/0963721413484756

Verdine, B. N., Golinkoff, R. M., Hirsh-Pasek, K., & Newcombe, N. S. (2014). Finding the missing piece: Blocks, puzzles, and shapes fuel school readiness. Trends in Neuroscience and Education, 3(1), 7-13. https://doi.org/10.1016/j.tine.2014.02.005

Verdine, B. N., Golinkoff, R. M., Hirsh-Pasek, K., & Newcombe, N. S. (2017). Links between spatial and mathematical skills across the preschool years. Monographs of the Society for Research in Child Development, 82(1), 1-150.

Verdine, B. N., Irwin, C. M., Golinkoff, R. M., & Hirsh-Pasek, K. (2014). Contributions of executive function and spatial skills to preschool mathematics achievement. Journal of Experimental Child Psychology, 126, 37-51. https://doi.org/10.1016/j.jecp.2014.02.012

Wai, J., Lubinski, D., & Benbow, C. P. (2009). Spatial ability for STEM domains: Aligning over 50 years of cumulative psychological knowledge solidifies its importance. Journal of Educational Psychology, 101(4), 817-835. https://doi.org/10.1037/a0016127

Zosh, J. M., Verdine, B. N., Filipowicz, A., Golinkoff, R. M., Hirsh-Pasek, K., & Newcombe, N. S. (2015). Talking shape: Parental language with electronic versus traditional shape sorters. Mind, Brain, and Education, 9(3), 136-144. https://doi.org/10.1111/mbe.12082