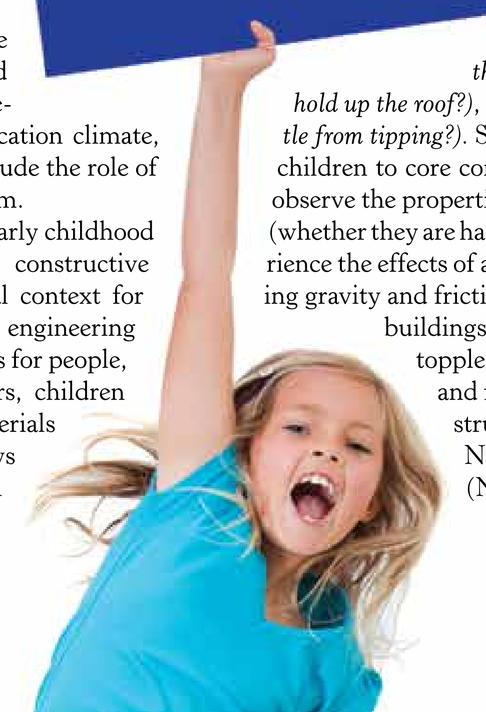
# GIMME AN “E”!

## Seven strategies for supporting the “E” in young children’s STEM learning

**By Cynthia Hoisington and Jeff Winokur**



Early childhood educators have long debated how science should be introduced and taught to preschoolers. In the current STEM education climate, this conversation has expanded to include the role of engineering in the preschool curriculum.

Why is there increased interest in early childhood engineering? First, young children’s constructive and dramatic play provides a natural context for identifying, addressing, and solving engineering design problems. As they create castles for people, corrals for horses, or garages for cars, children choose among available building materials and put them together in different ways with an eye to their structure’s function *(Is this fence high enough to keep the horses in?)*, strength *(Will the walls hold up the roof?)*, and stability *(How can I keep the castle from tipping?)*. Second, building experiences connect children to core concepts in physical science. Children observe the properties of the building materials they use (whether they are hard, soft, flexible, and so on) and experience the effects of applied and “natural” forces (including gravity and friction) acting on the materials and their buildings. Their buildings stand, sway, or topple depending on how these properties and forces interact and on how children’s structures are designed. Third, as the National Science Teachers Association (NSTA) Position Statement on Early

Childhood Science makes clear (NSTA 2013), research shows that young children are capable of conceptual understanding in the STEM disciplines. From a young age, children generate ideas that help them make sense of the physical world and how it works (Duschl, Schweingruber, and Shouse 2007). Although their explanations are often scientifically incorrect *(You need to use tall blocks to make tall buildings)*, they do stem from children's own reasoning about their prior observations and experiences with objects and materials. Young children can also develop the habits of mind that are integral to science and engineering, such as curiosity and persistence. And finally, *A Framework for K–12 Science Education* (NRC 2012) formally recognizes the close relationships among the STEM disciplines. It incorporates the idea that learning concepts and practices begin early and deepen over time and across grade levels. All of these factors, taken together, strongly suggest that preschool-age children should be engaged in a range of developmentally appropriate and playful learning experiences in physical, life, and Earth sciences that center on key concepts or "big ideas." These experiences have the capacity to build a foundation for children's later understanding of the core ideas, crosscutting concepts, and science and engineering practices outlined in the *Next Generation Science Standards* (NGSS Lead States 2013). It is important to emphasize that young children's STEM experiences should be expansive and not limited to the specific performance expectations for kindergarten and elementary grades.


**A designated block area and scheduled time to build support engineering in the early childhood classroom.**


PHOTOS COURTESY OF THE AUTHORS

**A block area includes a variety of building materials.**

Instructors and coaches in the professional development program *Cultivating Young Scientists* (CYS) worked with preschool teachers in Hartford, Connecticut, over five months as they implemented a unit on the topic of *Building Structures* (Chalufour and Worth 2004) in mixed-age classrooms of three-, four-, and five-year-old students. In this article, we share the seven overlapping and mutually reinforcing strategies teachers used that effectively supported children's learning in physical science and engineering.

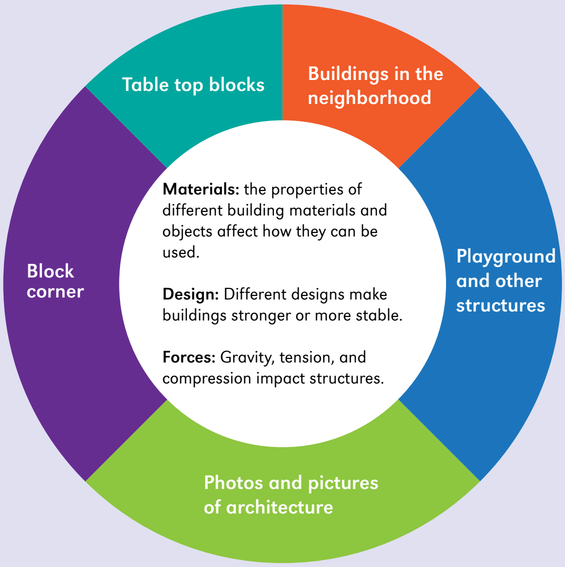
## Prepare the Environment for Investigating Structures

Preparing the environment means planning space, materials, and time for building explorations. CYS teachers arranged their existing "block areas" so that three to four children could build at one time and extended building into other learning areas. They collected a variety of building materials including wood, foam, and cardboard "blocks," intentionally incorporating different sizes, weights, shapes, and textures. Some teachers dug into closets, borrowed from other classrooms, scoured recycle centers, and collected common items (paper towel tubes, cardboard boxes) that could be transformed into building materials. Teachers integrated 20–40 minutes for building 2–3 times per week into their classroom schedules.

Teachers prepared to extend the unit to include ongoing explorations of the school and neighborhood buildings. They designated display spaces at children's eye level where photos, drawings, and descriptions of children's buildings would be posted as the unit progressed. In the meantime, they hung inspirational photos of houses, skyscrapers, and

## FIGURE 1.

Core building concepts/structures concepts.




bridges along with iconic structures such as the Eiffel Tower. When wall space was limited, teachers used the backs of shelf units or doors, or placed binders with plastic sleeves in the block area. Paper, pencils, clipboards, and collage materials were collected for children's 2-D and 3-D building representations. Construction paper "blocks" would provide additional representing options to younger children and children with limited fine-motor capacity. All of these opportunities would enable children to experience phenomena related to core building concepts. Figure 1 shows the relationship between the foundational concepts (at the center of the wheel) and opportunities for children to experience phenomena related to the concepts (outside of the wheel). Note that the impact of forces is less observable to children than the impact of materials and design on their structures.

In order to ensure safety during the unit, teachers limited the number of children allowed in the block area, and generated or reviewed existing rules with children such as *blocks are for building* and *builders can only knock down their own structures*. CYS instructors asked teachers to reconsider safety rules that restricted the height of children's structures and suggested new strategies such as requiring builders to wear hard hats, allowing ample space for building and closely monitoring children's tall buildings.

## Make Time for Teachers' Own Science and Engineering Investigations

In order to effectively plan for, facilitate, and assess children's learning in a building unit, preschool teachers need opportunities to participate in and reflect on their own collaborative building explorations. These experiences support their understanding of the relevant physical science concepts and immerse them in the practices essential to science and engineering (Wenglinsky and Silverstein 2006–2007). During CYS sessions, instructors facilitated teachers' inquiry-based explorations as teachers built tall towers, enclosures, and ramps; and investigated and represented neighborhood buildings. Teachers noticed that using dense versus less dense materials and different sizes, shapes, and textures made a difference in the strength and stability of their structures. They discovered that the foundation was a critical design feature, and that the need for stability imposed a constraint on how high they could build. Teachers also used science and engineering practices as they identified structural problems; drew and created models; measured their structures; debated about materials and design; identified patterns in what contributed to strong and stable structures; and generated ideas about successful building strategies. These experiences, along with discussions about how children learn in the content areas, familiarized teachers with how science and engineering practices might apply to children's building explorations.

**A student creates an enclosure with cardboard blocks.**

## Sequence Building Explorations Intentionally

Children build an understanding of core concepts over time and after many active experiences with related phenomena. CYS teachers intentionally sequenced children's ongoing building experiences from more *open* to more *focused* (Chalufour and Worth 2004). Initial open explorations over two or three weeks provided children with multiple opportunities to familiarize themselves with the building materials as they used them to build a variety of structures. Children noticed for example that cylinders sometimes rolled off their structures and that stacked wood blocks tended to slide. Early explorations leveled the playing field for children who had few prior experiences with building. They also provided time for children and teachers to adjust to new routines including representing and science talks, and provided teachers with preliminary data about their children's understanding and skills related to building.

Increasingly focused explorations reflected children's growing engineering skills, as well as their interests in building tall and in building homes for animals. Two towers investigations, lasting two to three weeks each, extended children's thinking about the properties of the building materials *(Which materials will build the tallest tower?)* and focused children's attention on design *(How can we make our towers tall, but also strong and stable?)*. A subsequent focused exploration of enclosures, stemming from children's interest in building animal homes, challenged children to create interior spaces, considering width and depth as well as height. Making walls, roofs, doors, and windows deepened their thinking about properties *(Should I use heavy or lights blocks for the roof?)* and design *(How can I add a door without the wall falling down?)*. Enclosures explorations also emphasized the concept of form and function *(How does a bunny's home need to be made differently than a giraffe's home?)*.

**A teacher observes, facilitates, and documents children's building explorations during a conversation in the Explore stage.**

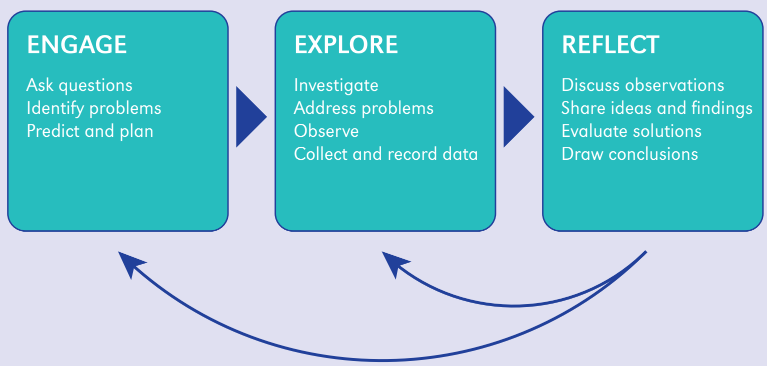
## Organize and Facilitate Children's "Minds-On" Building Explorations

Explicit frameworks help teachers organize children's science explorations and facilitate interactions that promote conceptual development and inquiry. CYS teachers used the *Engage, Explore, Reflect* (EER) cycle (Chalufour and Worth 2004) to ensure that each building exploration included multiple cycles of inquiry and a full range of minds-on as well as hands-on practices (see Figure 2).

The EER cycle also enabled teachers to embed prompts—comments and questions that promote inquiry—within each phase of the cycle (Table 1, p. 48). During *Engage* teachers used productive prompts that elicited children's prior knowledge about building structures and invited them to raise questions, identify problems, and make predictions. During the hands-on *Explore* teachers encouraged children to observe their buildings and identify, address, and solve building challenges. *Reflect* prompts helped children describe their building experiences using language, drawings, photos, and demonstration, and express their emerging ideas about how to make strong and stable structures. These prompts were multifunctional and contributed to students' language development and assessment practices.

**FIGURE 2.**

Engage-Explore-Reflect Cycle.



## TABLE 1.

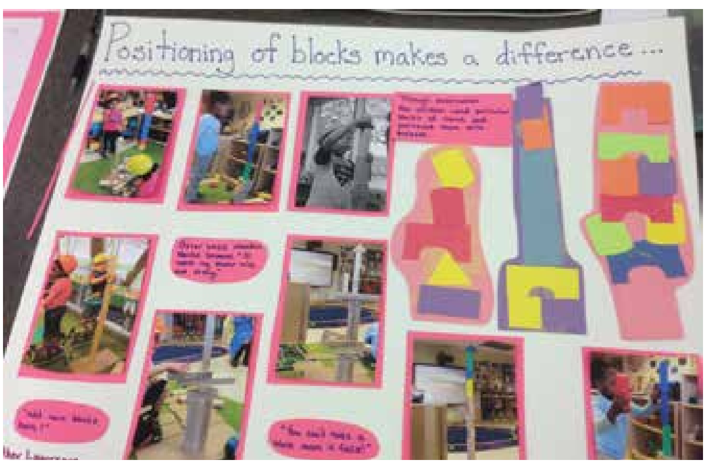
Examples of productive prompts.

| | Engage | Explore | Reflect |
|---|---|---|---|
| **Open Building Exploration** | Let's explore the different materials we have for building.<br><br>What do you notice about how these blocks look/feel?<br><br>How are they the same/ different?<br><br>What would you like to build? Which blocks or other materials might you use? | Can you tell me about your building and how you are making it?<br><br>Describe the different parts of your building.<br><br>I notice that you are using the ____blocks in this part and the ______blocks in that part.<br><br>How do the people/animals/ cars get into and out of the building? | Here are some photos I took of your structures. Would you like to describe them and how you made them?<br><br>How well did those blocks work in your building/that part of your building?<br><br>Why do you think they worked/didn't work so well?<br><br>What was the easiest/ hardest part of your structure to build? |
| **Focused Towers Exploration 1** | Let's look at photos of the tall structures you've been building. What do you notice about them?<br><br>Which blocks do you think will work best for making really tall towers?<br><br>Why do you think those will be best?<br><br>How could we find out? | Tell me about your tower and how you are building it.<br><br>I notice that you are using the ____blocks at the bottom/the top of your tower.<br><br>Have you tried adding any other kinds of blocks to your tower?<br><br>Here are some recording tools you can use to draw your tower. | Let's look at your drawings of your towers.<br><br>Can you describe what you used to build your tower? Why did you decide to put the ____blocks at the bottom/ top?<br><br>Which blocks do you think worked best for making really tall towers? Why do you think so? |
| **Focused Towers Exploration 2** | You made some really tall towers with the blocks and other materials.<br><br>How might we make our towers stronger and more stable?<br><br>How could we use this fan to find out how strong and stable the towers are? | Does your tower always fall down the same way? What parts stay standing?<br><br>It looks like you are: making your tower wider at the bottom/placing the blocks this way and then that way/ putting the same numbers of blocks on each side.<br><br>Let's draw and take photos of the towers. | Which of our towers were the strongest and most stable? How do you know?<br><br>What do you notice about the towers that stayed up when we put the fan on them? What about the towers that didn't stay up?<br><br>What are some different ways we found to make tall, strong, stable towers? |

## Integrate Opportunities for Language, Literacy, and Mathematics During Building Explorations

Science and engineering provide ideal contexts for language and literacy because communication is a critical aspect of both disciplines, and because children are naturally motivated to communicate their observations, discoveries, and ideas. Building explorations addressed foundational skills in each of the four *Common Core State Standards* literacy strands: Language, Speaking and Listening, Writing, and Reading. Teachers facilitated 5–10 minute science talks using a small-group format, photos, and children's building representations in order to better support the participation of all children including English learners (ELs). Using productive prompts, teachers scaffolded children's ability to use language for asking questions, describing, making comparisons, and expressing conclusions. Throughout the unit, teachers introduced and emphasized increasingly challenging vocabulary words including *build*, *blocks*, *structure*, and words that described the properties of the building materials. Teachers supported speaking and listening skills by encouraging children to maintain their focus on the topic, share their observations and ideas appropriately, and listen and respond to the contributions of other children.

Teachers fostered foundational writing and reading skills as they helped children create, share, and interpret representations. They invited children to use emergent writing to record data and modeled conventional writing as they transcribed children's dictation about their buildings. When teachers talked with children about their building drawings and stories, and read them fiction and nonfiction books about building (including *How a House Is Built* by Gail Gibbons and *I Fall Down* by Vicki Cobb), they supported children's development of pre-reading skills.




**A documentation panel makes children's ideas and thinking explicit.**

Structures explorations enabled teachers to teach math concepts, language, and skills for a purpose. Teachers encouraged children to measure their towers using standard and nonstandard measurement tools (their own bodies, unit blocks). They supported children's learning about spatial relationships ("How could you change the house so the teddy bear can stand up inside?") and patterns ("I notice that you placed foam, then wood, then foam, then wood. Why did you decide to use that pattern?").

## Collect Assessment Data Related to Building From a Variety of Sources

Assessment in science is a continuous process of uncovering children's knowledge and skills in relation to the core concepts and science and engineering practices. The best assessment probes are embedded in the curriculum and promote, as well as assess, conceptual learning and inquiry (Snow and Van Hemel 2008).

CYS teachers collected assessment data in the context of children's building explorations and as they facilitated children's learning and inquiry during each phase of the Engage-Explore-Reflect cycle. As teachers interacted with children during the *Explore* phase for example, they closely observed and recorded children's building behaviors; how they approached and persisted at building, used materials, designed their structures, and played and talked with each other. They made copies of children's building representations and transcribed what children said about them. During *Engage*, *Explore*, and *Reflect* conversations teachers noted how individual children communicated their building observations, experiences, and ideas. They could then individualize in the moment for children with a range of developmental levels, language, and social-emotional abilities by adding or removing materials, scaffolding language and vocabulary, or pairing with a more knowledgeable peer for example.

## Reflect On, Document, and Use Data from Children's Building Explorations

When teachers reflect on and document data from children's explorations, they make children's thinking and learning visible. This process also serves to inform ongoing planning. After the second towers exploration, CYS teachers collaboratively reflected on their building observations, photos, representations, and language samples. Each teacher created a documentation panel that illustrated what the teacher viewed as the most prominent aspects of his/her own children's learning up to that point. Individual panels highlighted for example, children's abilities to investigate


**A documentation panel highlights one child's exploration of various building materials.**

the properties of materials and design, and their impact on stability; identify and recreate patterns in their structures; and collect data about structures using a variety of measurement tools. The panels also illustrated children's thinking and emerging theories about building such as *You need blocks on the sides to keep buildings balanced*, *Wooden blocks make strong structures*, and *You have to place blocks carefully to make your buildings stay up*. Additionally, panels highlighted the playful, imaginative, and social nature of young children's authentic science and engineering explorations.

This collaborative reflection revealed that many children in classrooms were intentionally trying out and choosing different materials for different parts of their towers and developing tower-building strategies such as creating a hard base to build on, placing blocks carefully with an eye to balance, and even widening and strengthening their towers' foundations. Some children were verbally sharing their ideas about how to build tall towers (*Wood blocks work better at the bottom because they're heavy and "sturdy"; The tower stays up better if you build on something hard instead of the rug*) indicating their readiness to address a second design challenge such as building enclosures for animals of different sizes. It also enabled teachers to identify children in their classrooms who would benefit from more explicit language supports, additional options for representing, and intentional grouping with peers during explorations and conversations. Additionally, teachers determined that some children would benefit from ongoing open explorations and individualized support for investigating, using, and observing different building materials.

Teachers used their panels as the basis for follow-up conversations with children, further drawing out children's building interests and their ideas about building strong and stable structures. In doing so they obtained assessment information that informed their planning of enclosures explorations. They also gained a deeper understanding of young children, how they think and learn, and the types of experiences and interactions that foster their learning in science and engineering.

## Conclusion

Young children are curious and eager to engage in constructive and dramatic play by nature—but they must be taught to take advantage of these predispositions if they are to become more adept at thinking like scientists and engineers. Although preK performance expectations are not explicitly outlined in the *NGSS*, we have identified some of the ways in which young children's building experiences connect with and are foundational to developing specific practices, disciplinary core ideas, and crosscutting concepts (see Connecting to the *Next Generation Science Standards*).

Consistent implementation of the teaching strategies described in this article requires that preschool teachers have time, training, administrative support, and a commitment to science and engineering education for young children. But the potential payoff is tremendous—an opportunity for preschoolers and their teachers to jump into the world of 21st century STEM! ■

***Cynthia Hoisington* (choisington@edc.org) *is a curriculum and professional developer at Education Development Center (EDC) in Waltham, Massachusetts. Jeff Winokur is an early childhood and elementary science educator at EDC and at Wheelock College in Boston, Massachusetts.***

### References

Chalufour, I., and K. Worth. 2004. *Building structures with young children.* St. Paul, Minnesota: Redleaf Press.

**Children share their buildings and building strategies with the class during the Reflect stage.**

## Connecting to the *Next Generation Science Standards* (NGSS Lead States 2013)

The materials/lessons/activities outlined in this article are intended for use in PreK classrooms. Science experiences in PreK by their nature are foundational and relate to later learning in K–12 classrooms. As the *NGSS* performance expectations are for K–12, we have not included specific performance expectations, but have identified the disciplinary core ideas that are addressed to show the link between these foundational experiences and students' later learning.

| **Science and Engineering Practices** | |
|---|---|
| Asking Questions and Defining Problems<br><br>Developing and Using Models<br><br>Constructing Explanations and Designing Solutions | Students:<br>• identify a challenge or problem (build a tall tower or a home for animals).<br>• develop ideas and test which designs work best for their specific purposes.<br>• develop ideas about which materials work best under different circumstances. |
| **Disciplinary Core Ideas** | |
| ETS1.A: Defining an Engineering Problem<br>• Asking questions, making observations and gathering information are helpful in thinking about problems<br><br>ETS1.B: Developing Possible Solutions<br>• The ability to build and use physical models is an essential part of translating a design into a finished product.<br><br>PS1.A: Structure and Properties of Matter<br>• Matter can be described and classified by its observable properties. A variety of objects can be built up from a small set of pieces. | Students:<br>• investigate a range of building materials and designs and gather information about the benefits and challenges with each.<br>• continue to work on and improve upon their designs.<br>• use building materials in multiple ways based on their properties.<br>• go through cycles of building, knocking down, and rebuilding structures with blocks. |
| **Crosscutting Concepts** | |
| Structure and Function<br><br>Stability and Change | • Students design structures (e.g., towers) that meet a challenge or serve a purpose.<br>• Students explore how various designs affect stability. |

Duschl, R., H. Schweingruber, and A. Shouse, eds. 2007. *Taking science to school: Learning and teaching science in grades K–8.* Washington, DC: National Academies Press.

National Research Council (NRC). 2012. *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas.* Washington, DC: National Academies Press

NSTA. 2013. National Science Teachers Association Position Statement: Early Childhood Science Education. *www.nsta.org/about/positions/earlychildhood.aspx.*

NGSS Lead States. 2013. *Next Generation Science Standards: For states, by states.* Washington, DC: National Academies Press. *www.nextgenscience.org/next-generation-science-standards.*

Snow, C.E., and S.B. Van Hemel, eds. 2008. *Early childhood assessment: Why, what, and how.* Washington, DC: National Academies Press.

Wenglinsky, H., and S.C. Silverstein. 2006–2007. The science training teachers need. *Educational Leadership* 64 (4): 24–29.

### NSTA Connection

Visit *www.nsta.org/SC1509* for a list of resources.