ENGAGING Young Engineers

SECOND EDITION

Teaching Problem-Solving Skills Through STEM

Angi Stone-MacDonald, Kristen Wendell,
Anne Douglass, Mary Lu Love, & Amanda Wiehe Lopes

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Second Edition

by

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Dr. Stone-MacDonald is a professor and chair for the Special Education, Rehabilitation, and Counseling Department at California State University, San Bernardino. Dr. Angi Stone-MacDonald earned her doctorate from Indiana University in Special Education and African Studies, where she studied the role of culturally relevant curriculum and cultural beliefs about disabilities in the experiences of children with developmental disabilities at a special school in Tanzania. Dr. Stone-MacDonald has worked with children and adults with disabilities for the past two decades as a paraprofessional, teacher, consultant, and researcher, including most recently as a faculty member. Prior to moving to California State University, San Bernardino, she worked at the University of Massachusetts, Boston in the College of Education and Human Development and Early Education and Care in Inclusive Settings Program for 12 years. Her areas of research include early intervention, young children with autism, international inclusive education, and educator preparation for early intervention and early childhood special education. Dr. Stone-MacDonald serves her field and children and families with disabilities at the local, state, and national levels on a variety of committees and projects. She has been actively involved in state and local committees, organizations, and grant work with the state government to promote inclusion and adequate teacher preparation to work with children with disabilities in early childhood. She also taught STEM early childhood educator preparation courses and participated in STEM grants with the Commonwealth of Massachusetts. She has published several articles and four books highlighting inclusive education and early childhood special education.

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Dr. Wendell is an associate professor of mechanical engineering and education at Tufts University. She received a B.S. in mechanical and aerospace engineering from Princeton University, an M.S. in aeronautics and astronautics from Massachusetts Institute of Technology (MIT), and a Ph.D. in science education from Tufts University. Dr. Wendell's teaching and research interests include teacher education in science and engineering, the integration of engineering design into children's learning experiences, and knowledge building communities in undergraduate engineering education. An NSF CAREER award winner, she serves as PI or co-PI on NSF-funded projects that investigate curriculum and instructional supports for inclusive knowledge construction by engineering learners. Major projects emphasize community-based engineering curricula and professional development, engineering classroom discourse, design notebooking, undergraduate learning assistants, and responsive teaching for engineering. Kristen is an associate editor for the *Journal of Engineering Education*. She teaches courses in design, mechanics, electronics, and engineering education. Wendell previously served as assistant professor in the

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Mary Lu Love is a retired lecturer/director of early childhood services at the Institute for Community Inclusion at the University of Massachusetts Boston, where she managed grants, evaluation projects, and a variety of grant work in the early childhood field. Her undergraduate degree is from the State University of New York, Potsdam, where she graduated with a major in interdisciplinary social science and elementary education certification. She holds a master's degree in child care administration and has worked in early childhood education for 40 years as a teacher and administrator in public schools, Head Start, and private and nonprofit early childhood programs. She was a part of the 2011 Department of Early Education and Care–funded project Focusing a New Lens: STEM Professional Development for Early Education and Care Educators and Programs. Ms. Love has taught in higher education part time since 1986, teaching ethics, science, and mathematics for all young children and supervising internships. Her two adult children are a particle physicist and an architect.

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Dr. Lopes is passionate about creative approaches to learning. She has been a teacher, program leader, and curriculum consultant at early learning organizations across the U.S. including developing creative arts immersive early education and professional learning programs at the New York State Theater Institute, Seattle Art Museum, Seattle Children's Theater, Pacific Science Center, and Woodland Park Zoo. Through scholarship, Amanda investigates creative approaches to early learning through curriculum design, pedagogy, and leadership. She holds a Ph.D. in Early Childhood Education and Care from the University of Massachusetts Boston, an M.S.Ed in Early Childhood Education from the College of Saint Rose, and a B.A. in Theatre Arts from the University of Puget Sound. Amanda has been a guest lecturer and faculty at higher education programs across the United States including University of Massachusetts, Boston, University of Maryland, Baltimore County, Russell Sage College, Fisher College, and

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A Note to the Reader

Engineers use problem-solving methods to find solutions to our everyday problems. The engineering process is an ideal problem-solving framework for designing learning experiences that support science, technology, engineering, and math (STEM) learning and cognitive development with young children. Young children problem-solve in their daily play. As teachers and caregivers, we can promote the development of problem-solving and critical thinking skills through intentional activities that support young children's brain development. The concepts and methods of Universal Design for Learning (UDL) provide a structure for planning lessons to meet the needs of a range of children.

The first edition of this book came out of several years of work with early childhood educators through different projects to promote STEM-related learning outcomes. Some of these individuals and projects are discussed in the Acknowledgments. After completing a seminar with early educators on improving STEM education for children from birth to age 8, the authors presented the results of that seminar and the recommendation report at two national conferences: the Division for Early Childhood Conference and the National Association for the Education of Young Children Conference. We were approached by Paul H. Brookes Publishing Co. to write a book about using engineering in early childhood inclusive classrooms and jumped at the idea.

We devoted substantial time working together to deepen our theoretical foundation and think about what messages we wanted to convey. We were especially interested in demonstrating how educators and caregivers can intentionally teach problem solving and STEM through engineering with children from birth to age 3. After research and activity development, we piloted engineering activities for the five key thinking skills in infant, toddler, and preschool classrooms. We also interviewed the teachers about what worked and what changes were necessary to implement the engineering experiences most effectively. The teachers gave us lots of substantive feedback on the activities, materials, and presentation of activities, and we incorporated that feedback into the chapters.

The activities in this book can be taught in isolation or as a complete unit. Table I.1 provides an overview of the lessons featured in Chapters 3 through 7, where they are accompanied by detailed narratives about classroom enactment. Table I.2 lists 15 additional learning experiences that we have developed especially for the second edition. Both tables sort the learning experiences by age group and thinking skill.

For these learning experiences, we have suggested several books to use in conjunction with the activities. Other books can be used to teach the same concepts, but we chose these books because they are high-quality examples of children's literature and easily accessible to early childhood educators and parents. For the 15 new learning

Table I.1. Annotated thinking experiences (Chapters 3 to 7) by age group

	Infants	Toddlers	Preschoolers
Curious thinkers	With *Where's Spot?* by Eric Hill (2003), infants are provided with Hide-and-Seek experiences.	With *One Duck Stuck*, written by Phyllis Root (1998), toddlers explore what mud feels and looks like and compare and contrast it to water and dirt.	Preschoolers engage in "garden engineering" alongside Mr. McGreely, the main character of *Muncha! Muncha! Muncha!* by Candace Fleming (2002). They investigate sturdy garden walls by asking questions, making predictions, and building and testing.
Flexible thinkers	Through *Have You Seen My Cat?* by Eric Carle (2009), infants participate in a story and a game in which they must react to the problem of a missing cat.	Using *One Duck Stuck*, toddlers focus on the process of finding and excavating for objects stuck in dried mud.	Preschoolers consider all the ways that Mr. McGreely tries to solve his problem in the book *Muncha! Muncha! Muncha!* and they have the opportunity to plan at least two of their own solutions.
Persistent thinkers	*Baby Says Peekaboo!* by DK Publishing (2006) provides infants with large flaps that can be opened to reveal a hidden picture. Manipulating these flaps and searching to find a hidden object both require persistence.	With *Ten Dirty Pigs, Ten Clean Pigs*, written by Carol Roth (1999), toddlers focus on getting all 10 pigs clean and the process of scrubbing and cleaning to get the pig toys clean after mud play.	After more reading from *Muncha! Muncha! Muncha!*, preschoolers have the opportunity to build and persistently improve their own designs for protecting Mr. McGreely's vegetables.
Collaborative thinkers	Using the class-made *Find a Friend Book*, infants have the opportunity to strengthen positive and trusting relationships with others.	Using *One Duck Stuck*, toddlers focus on the process of finding objects stuck in wet mud using teamwork.	Using *The Tale of Peter Rabbit* by Beatrix Potter (2002), preschoolers consider the feelings that different individuals have in different situations and have an opportunity to work with a friend on a vegetable-carrier design challenge.
Reflective thinkers	Using a homemade baby faces game, infants have the opportunity to find a friend's picture.	With *One Duck Stuck*, toddlers have the opportunity to recall the story, retell it, and create a new ending.	Preschoolers have the opportunity to remember how they planned to solve a problem, how they created their initial solution, and what happened when they tried it out.

experiences in the second edition, we have aimed to highlight books that represent diverse children, families, and authors.

This book is divided into two sections. Section I explains the theory and evidence base behind our framework for children's STEM problem solving. Section II includes the activity chapters where we show educators and caregivers how to use the problem-solving framework to participate in engineering learning experiences with infants, toddlers, and preschoolers. In the beginning of this book, we provide a foundation for the book's content by describing the engineering design process, engineering design in early childhood, and the five foundational thinking skills critical to developing young and adult problem solvers: curious thinking, persistent thinking, flexible thinking, reflective thinking, and collaborative thinking. Each thinking skill is discussed in a chapter. Table I.3 provides examples of each thinking skill for each of the three age groups. These thinking skills prepare young children to be successful in STEM activities and to learn to think as problem solvers. Finally, these skills support positive social-emotional development, self-regulation, and the development of executive functioning.

Chapter 1 begins by unpacking engineering design, engineering design for young children, and the five foundational thinking skills (as listed in Table I.2) for engineering

Table I.2. Additional learning experiences (Chapter 8) by age group

	Infants	Toddlers	Preschoolers
Curious thinkers	*Peekaboo Morning* by Rachel Isadora. Spark curiosity by asking the infants what they see when you turn to each new page.	*Round Is a Mooncake* by Roseanne Thong. Encourage toddlers to be curious about shapes of various objects within their environment.	*Flotsam* by David Wiesner. Using recycled materials, preschoolers will build a prototype of a floating city, and test its success.
Flexible thinkers	*What Will Fit?* by Grace Lin. Using a container with different objects, ask the infants, "What will fit?"	*Fiesta!* (board book: bilingual Spanish-English) by Ginger Foglesong Guy, Encourage the toddlers to think of as many different kinds of materials to use as streamers.	*Muncha! Muncha! Muncha!* by Candace Fleming. Preschoolers will explore and investigate different paths into the garden without disturbing the wall they built in the previous lesson.
Persistent thinkers	*Baby Says,* by John Steptoe. Ask infants questions about what will happen and how the brother in the story feels.	*Off to See the Sea* by Nikki Grimes. Toddlers create new water toys combining various materials.	*Jabari Tries* by Gaia Cornwall. Preschoolers will build a flying machine out of blocks and other materials in the classroom.
Collaborative thinkers	*More, More, More, Said the Baby* by Vera B. Williams. Ask questions about the expressions of love by making it personal with the infants.	*One Springy*, *Singy Day* by Renée Kurilla. Toddlers will work together as a group to create musical instruments.	*Whole Whale* by Karen Yi. Preschoolers will work together to measure out the size of a blue whale using people, objects, and other means at their program, school, or in their neighborhood.
Reflective thinkers	*Ten, Nine, Eight* by Molly Bang. Ask questions on each page to link with infants' personal experiences.	*On Mother's Lap*, by Ann Herbert Scott. Toddlers will stack toys on a chair and compare what they have done with what is in the story.	*When Lola Visits* by Michelle Sterling. Preschoolers will create three pictures about what summer feels, tastes, and smells like.

and STEM. The premise of this book is twofold: First, young children can engage in a type of complex problem-solving called engineering design, and second, children's engagement with engineering design can support their higher order thinking skills and, at the same time, provide an exciting context for integrated STEM learning in the early years.

Chapter 2 discusses the UDL principles because we strongly believe that all children should have access through the application of UDL principles to high-quality STEM activities in an inclusive setting. After highlighting the evidence base for these principles for creating inclusive classrooms and lessons, we look at how the principles can help early childhood education teachers support young children with disabilities or delays as they engage in the engineering design process with their peers. We then discuss how we adapt the UDL principles to support children from birth to age 5 in inclusive settings. Finally, we discuss the templates we use in our engineering experiences to support young children using the UDL supports to make the problem-solving framework accessible to all young children.

In Section II (Chapters 3–9), we demonstrate how to use the early childhood UDL-focused problem-solving framework to teach the five thinking skills to infants, toddlers, and preschoolers. Each thinking-skill-based chapter in this section includes three activities (one at each age group: infant, toddler, and preschooler) to illustrate how to design activities for that thinking skill within the problem-solving framework. All the activities also incorporate UDL supports, so that all children in the classroom can

Table I.3. Developmental continuum of thinking skills

	Infants	Toddlers	Preschoolers
Curious thinkers wonder and actively explore people and things, especially the new and novel, and eventually abstract ideas.	• Use senses to explore the immediate environment • Explore and investigate ways to make something happen	• Show eagerness and interest in people, objects, and experiences • Use senses to explore and manipulate the environment • Investigate ways to make things happen in the environment	• Show interest in learning new things and trying new experiences • Ask questions to get information • Increasingly make independent choices
Persistent thinkers engage consistently in a challenging task and attempt multiple tries.	• Show interest in and excitement with familiar objects, people, and events • Repeat actions many times to achieve similar results	• Show interest in favorite activities over and over again • Find pleasure in causing things to happen • Try several times until successful	• Attend for extended periods of time when engaged, despite distractions or interruptions • Seek help when encountering a problem • Create and carry out a plan to solve a problem
Flexible thinkers adjust to changing information and goals, anticipate and plan for future scenarios, and consider new or different perspectives to "think outside the box."	• React differently to people, events, and settings • Try several ways to reach simple goals	• With adult support, make transitions between different tasks or activities • Use different ways of completing a task • Shift attention as needed • Observe and imitate how other people solve problems	• Try different ways to solve a problem • Adjust to new settings and people with minimal assistance • Exhibit adaptability, imagination, and inventiveness when attempting to solve a problem • Draw on different resources to solve a problem
Collaborative thinkers coordinate two or more people's actions in order to achieve a common goal.	• Engage in joint attention • Imitate the physical actions of others • Play simple games • Anticipate predictable interactions • Develop secure attachments with trusted adults	• Use adults as a safety point to explore and return to • Engage in parallel play with peers • Use trusted adults as a secure base from which to explore the world • Show concern about the feelings of others	• Recognize basic emotional reactions of others and their causes • Notice and accept that others' feelings about a situation might be different from their own
Reflective thinkers recall an object or event in their minds, remember it later, analyze it, and then plan to carry out next steps.	• Recognize familiar people, places, and objects • Look for hidden objects based on their previous location • Recognize familiar people and objects by name	• Look for familiar people and recognize names • Make connections between objects and events • Recall familiar people • Know familiar routines	• Try different ways to solve a problem • Talk about experiences to evaluate and understand them • Draw on daily experiences and apply this knowledge to similar situations

participate in these engineering experiences. Each chapter follows the same sequence. In the thinking skill chapters, we do the following:

- Briefly revisit the applicable thinking skill for that chapter and why it is foundational to STEM readiness for young children
- Explain a routine or activity that can be used at each age level (infant, toddler, or preschooler) to teach the thinking skill, providing planning forms and templates to support educators in these activities and to plan additional activities
- Highlight UDL practices for six children described in the "Profile Children" section that follows (two at each age level) and offer modifications and suggestions for these children with special needs or who are English language learners (each chapter shows teachers how to plan intentionally to meet the needs of all children)

- Link all activities to standards/developmental milestones across domains
- Offer additional suggestions to support various learners in the class

In each of Chapters 3 to 7, we present annotated learning experiences to teach specific thinking skills to each of the three age groups and provide the tools to implement these activities in an early childhood setting. We walk through the activities, the planning process, and the implementation of the activities. Each activity uses a portion of the engineering design process to teach problem-solving skills. These activities illustrate methods to teach the prerequisite problem-solving and thinking skills that young children need to be successful in STEM learning. In addition, the activities presented in this book are accessible to all young children in the classroom through the implementation of UDL guidelines that have been adapted for early childhood education (Center for Applied Special Technology [CAST], 2012b). Each of these engineering experiences at a given age level uses the same template. The infant activities focus on the prerequisite skills for different aspects of problem solving, whereas the preschool activities take children through an entire step in the engineering process. All activities are linked to standards addressed in various infant-toddler and preschool curricula used in settings such as Head Start as well as the kindergarten Common Core standards and Next Generation Science Standards to support school readiness (see Table I.2).

Many of the activities presented in this book could be used to teach more than one or even all the thinking skills, but we have chosen to use the described activities in each chapter to highlight how to teach that specific skill. Using the templates, educators and caregivers can create customized lessons around an activity to teach children a different skill or focus on different outcomes depending on the goals and standards for the lesson. For example, in Chapter 7, the toddler collaborative thinking activity "Mud Excavations" is a great activity for teaching flexible thinking, but this activity can also be used with preschoolers and can teach persistent and curious thinking. We have chosen to use the activity for collaborative thinking and with toddlers to show very intentional ways to teach that skill with that age group.

Chapters 3–7 highlight UDL supports for six children, two at each age level, who need additional supports to maximize their learning. The following "Profile Children" section provides more information about these children before ways to address their unique learning needs during the STEM activities are discussed. As we demonstrate the various activities, we emphasize strategies within the UDL framework to support all children in your setting. Finally, we will provide blank planning and UDL forms as appendixes to help educators plan additional activities to teach the specific thinking skills using the UDL and problem-solving framework. The completed planning materials are embedded in the chapters and appear as blank forms in the appendixes.

Chapter 8 features 15 additional learning experiences—one for infants, toddlers, and preschoolers for each thinking skill.

Chapter 9 discusses how to help educators apply this framework to their practice and adult learning and how to model problem solving as adults in their classroom and with their students.

Profile Children

The children described in this section represent real children we have worked with who are members of inclusive early childhood settings in the United States. These children are featured in the book's chapters to help illustrate specifically and generally how to use early childhood UDL principles to support young children of all abilities. The examples include children who have different special needs and some who are English language learners. We hope the profile children will be similar to children you have in your own classroom who can learn problem solving and practice the five thinking skills through the activities in the book. In the templates, look for the UDL supports included specifically for one of these children and the supports that will help all children in the classroom develop problem-solving and complex thinking skills.

Julia, Infant Julia is a 12-month-old girl who was born at 29 weeks and spent parts of her first 6 months in the hospital due to underdeveloped lungs and low birth weight. Despite these health challenges, Julia is doing very well. She lives at home with her mother, father, two older brothers (6 and 8), one sister (9), and her grandmother. She is babbling, can pull herself up, and is taking some steps with the support of an adult or a railing. She crawls all around the house and is very excited to explore the living room and kitchen. She is very excited to point to things and ask for them. Her parents have taught her some sign language that she uses, such as "more," "juice," "all done," and "milk." She is eating finger foods and has a good appetite. Julia sleeps through the night most of the time. Julia loves to imitate what her mother and siblings are doing. She plays well with her brothers and sister, but they do not always want to play with her. She likes to shake her head no, point to something out of reach, or wave bye-bye. She is starting to show inflection when she is babbling and has almost said "mama" and "dada." She enjoys hearing books, and her favorites are those by Eric Carle and Dr. Seuss. She thinks they are very funny. She also likes books with soft and crinkly parts.

Julia attends a child care center during the day while her parents are at work. She goes to the center Monday through Thursday and is at home with her grandmother most Fridays. On the weekends and in the evenings, she often tags along to sports and lessons with one of her older siblings.

David, Infant David is 14 months old and was born with Down syndrome and a congenital heart defect. He had open heart surgery when he was 6 months old. In his first year, David often got ear infections and has recently had a set of pressure-equalizing (PE) ear tubes placed in his ears. David lives at home with his parents and is an only child. Currently, David is not crawling or walking, but he can sit up on his own and scoots himself along the floor. He has good head control and enjoys tummy time. He is a poor sleeper at night but can take long naps. This results in crankiness and an uncertain progress at times for his various therapies because he is so tired during sessions.

David is working with a speech-language pathologist through the early intervention program and is working on oral stimulation, oral-motor awareness, and multiple experiences with oral sensory stimulation. In speech therapy visits, the therapist has used short descriptive sentences to describe toys David picked up. After 2 or 3 weeks of speech therapy, David's mother became adept at these techniques and began describing his activities as he did them so that he could hear them and associate the object he had with the words he heard. David is making a few sounds, and his parents have taught him some sign language. At this time, his mother is a stay-at-home parent and works with him every day on therapy goals. She takes him to a mommy-and-me playgroup at the early intervention site and also to the children's hospital each week for his physical therapy appointment. He enjoys going to the pool and floating in the water with his parents. His parents want to enroll him in a child care center when he is 18 months old but are concerned about his many therapies and if the center will be able to handle all his needs.

Tam, Toddler Tam, a 20-month-old girl, was referred to the early intervention program for a developmental delay 6 months ago because she was failing to thrive and had some heart issues. She has been receiving services for early intervention for 4 months. Tam's parents and grandparents are from Vietnam, but Tam was born in the United States. At home, they speak Vietnamese. Tam lives with her mother, father, and 4-year-old sister, and her maternal grandparents live nearby and often care for the children. Tam and her mother see an early intervention specialist and an occupational therapist in the home once a week.

With the support of the occupational therapist, Tam is learning to eat baby food, hold an adapted spoon, and drink small amounts of liquid from a sippy cup. Her mother reports that Tam needs assistance with dressing but enjoys bath time. Tam plays by reaching for and batting toys, using Picture Communication Symbols the family has been given by the early intervention specialist, and making sounds or gestures. The symbols have the words in both English and Vietnamese so her parents and grandparents can understand what each picture means from both the picture and the word. Tam is very interactive with those around her and tries to join in imitative sound play by making her own sounds following sounds made by others. She is starting to speak in syllables. Her mother told the early intervention specialists that Tam will use gestures and sounds to let her mom and dad know when she wants something, such as when she wants to be picked up, when she is full, or if she does not like a particular food. Tam will cry and fuss when she is not understood. She is motivated to move to get her toys, although she is not able to move far without assistance. Tam appears to enjoy being with adults and other children and likes being read to. When with other children, especially her sister, Tam watches them, laughs, and attempts to imitate sounds they make. She loves toys that make sounds and is more motivated to be happy when given one of these toys. She especially likes toys that play tunes.

Jessie, Toddler Jessie is 2 years, 5 months old. Her mother is from India and her father is an American of Swedish heritage. After a full term of 9 months, her mother gave birth to her via normal delivery. As an infant, she was healthy and breastfed by her mother. They would like to raise her as a bilingual child who can also speak Hindi. Both parents speak Hindi and English. Her father is a real-estate agent, and her mother is a professor. They met in India. Jessie met her early developmental milestones and started walking at 10 months and talking at 13 months but was struggling with social-emotional development. She did not like to separate from her family and had tantrums easily. Jessie does not have a diagnosed disability but has been assessed for early intervention based on social-emotional concerns from both the family and the child care center. She started speaking mostly in English but then shifted to using both languages for single words to two-word phrases. She seems to already recognize that she speaks Hindi at home mostly but English at school, and her vocabulary in both languages is growing.

When she was 1 year old, her mother decided to go back to work, and Jessie started going to a family child care center in the neighborhood. At first, she had difficulty adjusting to the setting, because Jessie would cry every time her mother left the house or left her at the child care center. It seemed that she was very attached to her mother, but gradually she stopped crying and started to play with the other children. Her motor and cognitive development are typical, and she has excellent visual-spatial skills and hand–eye coordination. Jessie has several playmates at her family child care center. She talks with the other children and initiates games and conversations, but she can lose her temper very quickly if she does not get what she wants. She can engage in violent temper tantrums in which she kicks and screams and throws herself to the floor. She does not hurt her peers during her tantrums, but the other children usually go to another part of the room or another room if there are several adults. She particularly likes playing with the older children. Her favorite toys are building blocks, balls, and her veterinarian kit. She likes to build large structures but gets upset when the boys knock them down, purposely or accidentally. She likes to play with the family dog and cat. She is also fond of scribbling and asks for crayons.

Brandon, Preschooler Brandon is a 3-year-old child with autism. He participates in an inclusive preschool classroom with 18 typically developing children and 3 other children with various disabilities. Brandon lives with his mother and two older sisters at home: Sara, who is in second grade, and Hilary, who is in sixth grade. Brandon uses a communication device to help him communicate and likes electronic toys and games, as well as playing with his toy trains. He has approximately 15 words to communicate verbally and uses signs or his communication device for more complex messages. He understands many picture symbols and recently started to use an iPad with all his symbols on it. His mother is happy to have a device that is easier to program with his communication boards and often asks Brandon's sisters to help her program new words from school or new menus of choices related to a community outing. Brandon loves his new iPad and is more interested in using it to communicate and showing his skills to his classmates than he had been with his old basic electronic communicator.

Brandon likes to go to school and enjoys free play and gym. He is more engaged in his reading activities when they involve a train, electronics, or his iPad, because these are his favorite things. Brandon has slightly delayed cognitive development, but his teachers and family hope that his cognitive development will improve as his communication and language improve. He seeks interaction from his peers, but sometimes he is frustrated when they cannot understand what he wants or he does not get a turn in a game, and he will hit or scream as a result. His inclusive preschool teacher is working with Brandon to find more positive ways for him to interact with his peers and to ask to be part of their activities. When outside on the playground, Brandon sometimes has trouble interacting with his peers appropriately because he does not use a device when outside and therefore is more limited in his communication capabilities. Because he is good at kicking and throwing, his peers like to play games with him and ride tricycles together.

José, Preschooler José is a 4 1/2-year-old boy who attends a preschool program in his city. He is friendly and cooperative and follows the rules and routines of his preschool program. He enjoys playing with toys and outdoor play equipment. He plays cooperatively with his peers, shares, and takes turns. José initiates hands-on activities independently and sustains attention until they are completed. He demonstrates curiosity through physical exploration. His favorite place to play is the dramatic play center.

José can draw shapes and simple pictures. His fine and gross motor skills and social-emotional development are age appropriate. José can follow two- to three-step directions. He enjoys looking at books and sitting with his teacher listening to stories, particularly ones that have pictures. However, listening to a story in a group and responding appropriately to related questions are difficult tasks for José. Attention in these tasks is variable. After 4 or 5 minutes, he tends to wander visually or get up and start walking around the classroom. At home with his family, José speaks Spanish, and his English expressive vocabulary is limited. His Spanish vocabulary and language skills seem more developed. None of his teachers speaks Spanish. He will respond to adult questions but prefers to speak in Spanish and will interact with peers in the classroom in Spanish if other Spanish-speaking children are in the same area. He communicates frequently during free play and center time. When faced with a problem, he typically gives up, gives in, or walks away instead of using language to express himself. He generally describes objects by using color words. He asks questions infrequently, voicing them with inflection (e.g., "Mommy work?").

José can sort objects by shape, size, and color. He can name colors and identify shapes by pointing. José names simple objects and pictures in his classroom and can address his classmates by name. He demonstrates an emerging interest in letters and words, as evidenced by his journal writing. José can count by rote to 5 but is still working on his understanding of patterns.

Each of these children has unique circumstances but also strengths and needs that educators will recognize in children in their own inclusive classrooms. The UDL planning sheets and completed templates will help teachers plan for children with similar needs in their own classrooms and develop ideas to support all children so they can fully participate in the STEM activities.

Universal Design for Learning Supports Unit Planning Sheets

A summary of the UDL supports used across the unit for each age group is included in the appendixes on a form called the Early Childhood UDL Planning Sheet. The Early Childhood UDL Planning Sheet summarizes the supports across the different activities based on the type of support (e.g., materials, methods of assessment) and whether the support is designed for an individual profile child or can be made available to any child who needs that additional scaffolding.

REFERENCES

Carle, E. (2009). *Have you seen my cat?* Little Simon.

Center for Applied Special Technology. (2012). Research evidence: National design on universal design for learning. https://udlguidelines.cast.org/more/research-evidence#:~:text=UDL%20is%20based%20upon%20the,the%20results%3B%20they%20are%20prominent

DK Publishing. (2006). *Baby says peekaboo!* Dorling Kindersley.

Fleming, C. (2002). *Muncha! Muncha! Muncha!* Atheneum Books.

Hill, E. (2003). *Where's Spot?* Putnam.

Potter, B. (2002/1902). *The tale of Peter Rabbit*. Warne.

Root, P. (1998). *One duck stuck*. Candlewick Press.

Roth, C. (1999). *Ten dirty pigs, ten clean pigs*. North-South Books.

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The seminar engaged participants in understanding and discussing the state of the field in STEM education for children from birth to 5 years old and in after-school care and the state of professional development for early childhood educators in STEM education. Participants examined what gaps and needs existed and offered suggestions to strengthen STEM education. Together with experts in the field, participants developed a set of recommendations for improved professional development for early childhood educators in STEM education (see Stone-MacDonald et al., 2011).

We would like to thank the Region 6 Educator and Provider Support Collaborative and Region 4 Professional Development Partnership of the Child Care Resource Center in Massachusetts for the opportunity to work with early educators across our state to advance the field in the area of STEM education. We would also like to thank the experts and early educators who participated in the seminar, from whom we learned so much. We would also like to thank the participants in our conference presentations at the National Association for the Education of Young Children and Division for Early Childhood in 2012 for their thoughtful feedback about our work, which generated some of the initial ideas in the book.

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For the idea to use the book *Muncha! Muncha! Muncha!* (Fleming, 2002) to launch engineering challenges, we are indebted to Brandon Lee. We are also grateful to the Center for Engineering Education and Outreach at Tufts University for modeling so effectively how to integrate children's literature and engineering. We thank Marylin Bennett and her early childhood colleagues at Marlborough Public Schools for inspiring the four-part emergent engineering cycle. Kathy Clunis D'Andrea awed us with her talent for posing thoughtful question to nudge children to the next level of problem solving. For the second edition, the Tufts and Vanderbilt Design Talks team helped us better highlight the crucial role of social and ethical reasoning in engineering design. In addition, we would like to thank people who came to our presentations about this work and pushed us to think more critically about the cultural messages and cultural sustainability in our lesson designs.

We would like to thank Keith MacDonald for the wonderful and engaging pictures in this book. We all have a greater appreciation for the hard work it takes to create an excellent photograph that captures the moment of excitement and learning, particularly with young children who are always on the go.

We would also like to thank the UMass Boston students whom we taught in early childhood educator preparation classes between the first and second editions of this book, particularly those in ECHD 441 Science and Math for All Young Children, for inspiring us to keep playing, learning, and writing more lessons to support early educators.

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REFERENCES

Fleming, C. (2002). *Muncha! Muncha! Muncha!* Atheneum Books.

Stone-MacDonald, A., Bartolini, V. L., Douglass, A., & Love, M. L. (2011). Focusing a new lens: STEM professional development for early education and care educators and programs. https://scholarworks.umb.edu/cgi/viewcontent.cgi?article=1003&context=curriculum_faculty_pubs

I

Why Engineering and Problem Solving Are Important in Early Childhood Inclusive Classrooms

1

Young Children Are Natural Problem Solvers

A Framework Overview

Excerpted from "Engaging Young Engineers: Teaching Problem-Solving Skills Through STEM, Second Edition"
by Angi Stone-MacDonald, Ph.D., Kristen Wendell, Ph.D., Anne Douglass, Ph.D., Mary Lu Love, M.S., Amanda Wiehe Lopes, Ph.D.

There are two big ideas behind this book. The first is that young children can be emergent engineers: preschoolers, toddlers, and even infants exhibit many of the foundational skills used in the complex problem-solving activity of engineering design. The second big idea is that children's emergent engineering activities can develop their higher order thinking skills and at the same time provide an exciting context for integrated science, technology, engineering, and mathematics (STEM) learning in the early years. When we talk about STEM, we are not referring to stand-alone science, technology, engineering, or math activities that are isolated by subject area. Instead, we mean integrated STEM *learning*, where multifaceted experiences provide opportunities for children to participate in scientific and mathematical reasoning, computer and other technology use, and engineering design—all together within the same activity.

This book proposes a framework for children's STEM problem solving. This problem-solving framework is based on engineering design: It uses engineering design problems as content and context for all four STEM disciplines to be practiced simultaneously. Although engineering is one of the distinct STEM fields (it is the E in STEM), it can also be an activity in which knowledge, skills, and habits of mind from all four STEM disciplines are woven together. Of the four words represented by the acronym STEM, the word *engineering* is often perceived by educators, parents, and caregivers as representing something more daunting or unattainable than science, math, or technology. But really, at its core engineering is the systematic solving of human problems by connecting science, math, and technology with empathy and creativity. Engineers and engineering are all around us, every day, and everyone engages in many engineering-like problem-solving activities. One of the goals of this book is to demystify engineering design and the skills that contribute to it.

In the problem-solving framework featured in this book, children and adults work together through four phases of engineering design that are appropriate for young children. These phases are as follows:

1. Think about it.
2. Try it.
3. Fix it.
4. Share it.

This chapter describes what children and adults do in each of these phases. It also describes five important higher order thinking skills that are essential for engineering designers and for young problem solvers. These thinking skills are as follows:

1. Curious thinking
2. Persistent thinking
3. Flexible thinking
4. Reflective thinking
5. Collaborative thinking

The enhancement of these higher order thinking skills is the ultimate goal of engaging children in emergent engineering problem solving.

This introductory chapter begins with a summary of recent successful approaches to foster STEM learning among children from birth to age 5. Next we focus on the E in

STEM and demystify engineering with some definitions of key terms and an overview of the engineering design process. We then turn to our problem-solving framework for emergent engineering. We describe its four main phases and its five foundational thinking skills. Finally, we set the problem-solving framework in the context of what we know about childhood development and standards for early education and care.

APPROACHES TO STEM LEARNING: BIRTH TO AGE 5

Developmental research affirms that young children and STEM go together. For example, research tells us that preschoolers and some verbal toddlers can learn concepts in specific science domains (Gelman & Brenneman, 2004), exhibit reasoning skills for making sense of science investigations (Gopnik, 2012), use number sense to estimate and compare quantities (Sarama & Clements, 2003), apply algorithmic thinking to create simple computer programs (Bers, 2017), and collaboratively construct and troubleshoot in a makerspace (Wohlwend et al., 2017). Preverbal toddlers and infants also show early number sense and an understanding of relative quantity (Dehaene, 1997), and they demonstrate knowledge of important categories in physical science (e.g., which things stay up by themselves and which things need support; Hespos & Baillargeon, 2008) and life science (e.g., animal and nonanimal; Rakison & Poulin-Dubois, 2001). They can interact with and respond positively to developmentally appropriate computer technologies (e.g., digital photos of important people, videos of themselves solving problems; National Association for the Education of Young Children [NAEYC] & the Fred Rogers Center for Early Learning and Children's Media at Saint Vincent College, 2012).

This body of knowledge about young children's abilities indicates that they have many resources to apply to activities that involve science, mathematics, and technology. We believe these resources also equip children for the engineering-based problem-solving framework used throughout this book. Many other early childhood educators and researchers have laid the groundwork for our particular approach to engaging young children in inclusive STEM learning activities. This section describes the work of some key contributors to early childhood science, math, technology, or engineering education. Their approaches give children opportunities to construct and represent their own knowledge through hands-on experiences facilitated by responsive adults. These contributions form much of the basis of what educators know about children's potential for STEM learning in the preschool years. Less is known about what it looks like when infants and toddlers are included in early STEM activities, and for that reason, we intentionally include those younger age groups in our work.

One important contribution to early childhood mathematics education is the Building Blocks™ PreK curriculum, which reveals the incredible learning trajectories that young children can follow in mathematics if ideally supported by research-based learning experiences (Building Blocks, 2013). Based on Doug Clement and Julie Sarama's extensive, federally funded nationwide studies of children and mathematics, the Building Blocks curriculum, manipulative kits, and software applications focus on finding mathematics in children's everyday activities, from art to songs to building blocks (Sarama & Clements, 2003). The focus is on children "mathematizing" by representing their activities with mathematical actions such as counting and transforming shapes. In support of children's progress along the learning trajectories developed by the Building Blocks researchers, early childhood math educator Greg Nelson (2007) has pioneered a Montessori-based method of providing structured manipulatives and activities that preschool children choose and use to guide their development of number sense. More recently, curriculum development efforts like Make Connections (TERC, 2018) and Storytelling Math picture books (Lin, 2020) have focused on supporting caregivers and children from all backgrounds in finding the mathematics in the world around them. In addition, Teaching Strategies GOLD® is a child assessment system used in many states for ages birth to third grade that is aligned to state and national standards and used in Early Head Start and Head Start (Heroman, Burts, Berke & Bickart, 2010). It is associated with the Creative Curriculum but can be used with other curricula and "includes items specifically addressing inquiry science skills, life science, physical science, earth science, and technology and tool use" (Donegan-Ritter & Zan, 2017, p. 224).

In early childhood science education, one widely used and praised inquiry-based approach is the Young Scientists Series created by Karen Worth and Ingrid Chalufour and their colleagues. Successfully applied across many different early childhood settings, this curriculum emphasizes hands-on experiences in which children construct and record knowledge about nature (Chalufour & Worth, 2003), structures (Chalufour & Worth, 2004), and water (Chalufour & Worth, 2005) under the guidance of expert adult facilitation. Chalufour and Worth stress the importance of sustained time for children to explore the properties of physical objects and materials—both those in nature and those that they construct themselves. Adults play a key role in posing questions about children's explorations and documenting their work and their discoveries.

The Ramps and Pathways approach developed by Rheta deVries and Christina Sales (2011) has much in common with the explorations of physical structures in the Young Scientists Series. What differentiates Ramps and Pathways is its focus on balls in motion and its explicitly constructivist take on developing children's physical science knowledge, inquiry skills, and design strategies. Children explore the never-ending possibilities for making balls move along tracks.

The Preschool Pathways to Science (PrePS™) approach (Gelman et al., 2009) is a method for structuring and implementing a preschool science curriculum that is based on domain-specific constructivist theories and cognitive scientists' findings about young children's mental development. It represents a synthesis of emphasizing science process skills, science language, and core science concepts around which a long (from several months to a full year) sequence of science explorations is organized.

Since the publication of the Next Generation Science Standards (NGSS Lead States, 2013), which include engineering design, many new K–12 engineering curriculum materials have become available. There have also been several efforts to develop engineering-specific learning sequences for younger children. The preschool Wee Engineer® curriculum from Engineering Is Elementary challenges preschoolers to design and test rafts, fans, wrecking balls, and noisemakers (EiE, 2022). The Head Start on Engineering / Ingeniería y Head Start program offers activities that empower families to use engineering to help their children thrive (TERC, 2022).

Several other current approaches to young children's STEM learning, including many makerspace programs, have their roots in Seymour Papert's (1980) theory of constructionism. Proponents of this theory view intellectual growth as the consequence of working on personally meaningful ideas with personally meaningful objects (both on computers and in tangible 3-D). Extending Piaget's theory of constructivism, constructionists advocate for children to have access to rich learning environments and powerful tools that can lead them to construct powerful ideas. This idea is consistent with the perspective behind makerspaces, the premise that people learn and grow by exploring materials and expressing themselves with handmade artifacts. Early childhood makerspaces offer children a wide range of carefully selected and organized materials and tools that are appropriate for children's small size and still-developing motor skills. The materials in a makerspace intentionally span a range of properties (e.g., flexibility, reflectivity, stability, ability to connect to other materials) so that children can explore many options for making creations that look and behave as they desire. Some makerspace tools have more specialized capabilities than those typically available in an early childhood classroom, such as cardboard cutting, colored LED lights, and programmable motors, but these special tools are not necessary. The key elements of makerspace programs are a neatly and beautifully displayed variety of supplies and a supportive community of helpers. With this support, even very young children can explore and create personally meaningfully artifacts.

In the realm of more specialized tools, the child-friendly computer programming language ScratchJr (Bers, 2017; Bers & Resnick, 2014), intended for children as young as 4 years old, is an example of a computer-based constructionist tool for children's exploration of personally meaningful ideas. Available on the web (http://www.scratchjr.org) and as an app for tablet computers, ScratchJr consists of a set of icons that can be dragged and dropped into place to command an on-screen "sprite" to act out a story of the child's own creation. Explorations with ScratchJr encourage computational thinking, which involves applying mathematical and geometric reasoning to create an algorithm for a behavior. ScratchJr is reminiscent of Logo, an earlier constructionist computer programming platform designed for children. Early childhood activities with LEGO bricks (Portsmore, 2010), LEGO Mindstorms robotics sets (Bers, 2008), and even wooden unit blocks can also be examples of constructionist STEM experiences when the child is the one generating the ideas about how to use the tools.

ENGINEERING DESIGN DEMYSTIFIED

The learning activities in this book provide opportunities for young children to engage in something that we call *emergent engineering*. These emergent engineering activities are inspired by the way that adults participate in more sophisticated engineering design efforts. Although the results of engineering design are all around us, many people have an incomplete understanding of what engineers do or a negative impression about what engineering is. Before describing what young children's emergent engineering looks like, let us take a moment to unpack engineering design from an adult's perspective.

What Is Design?

Design is a very common term used in many different ways, but we use it to talk about any human activity with the conscious goal of creating an artifact or process that will solve an open-ended problem. An open-ended problem is one that has multiple acceptable solutions. Design involves bringing about change in the physical and social world and changing a situation from the way it is to the way one wishes it to be (Simon, 1996). Often, design requires responding to an ill-structured problem. This kind of problem lacks all the information and structure needed to solve it. People engage in design to solve many kinds of problems, such as expressing themselves in words and graphics, decorating their homes and workplaces, putting food on the table, creating new organizations and communities, and challenging inequalities. At its best, when designers from all communities and backgrounds are included, design enables us "to build a better world, a world where many worlds fit" (Costanza-Chock, 2020, p. xvii). Design is also a key part of many professional domains, ranging from organizational design to fashion design, interior design, artistic design, graphic design, and architectural design.

What Is Engineering Design?

Engineering design is one of many types of design activities, and it can be defined more specifically than design in general. It is the organized development and testing—through the connection of math and science to empathy and creativity—of artifacts or processes that perform a desired function within specified limits (Davis & Gibbin, 2002; Dym & Little, 2004). The results of engineering design can be three-dimensional, such as vehicles and water filters; two-dimensional, such as drawings and printed sets of instructions; or digital, such as computer software.

A well-known example of engineering design applied to an ill-structured problem is the "shopping cart challenge" taken on by the California-based design firm IDEO. For a television documentary on innovation, their team of designers was asked to take the familiar grocery store shopping cart and redesign it in just 5 days (Kelley & Littman, 2001). They were given no specific goals except to make a better shopping cart and no guidelines except to get it done within 5 days. The IDEO design team had to figure out whom to consult about the current shopping cart experience, what to focus on as the most frustrating and important problems of existing shopping carts, what level of safety to maintain, how much money to spend on materials, and whether to design and construct one or many prototypes to test out their ideas. They had to anticipate and prevent potential negative consequences of the shopping cart features they brainstormed, and they needed to ask themselves whose perspectives and well-being they were failing to consider and how they could do better. Math, science, empathy, moral reasoning, creativity, and emotional regulation all played a role in their work. There was no specified path to follow to create a better shopping cart. This lack of a pathway is the essence of ill-structured engineering design work. Not only did the engineers have to figure out a solution to the problem, but they also had to figure out what steps to take to achieve that solution and how to take them responsibly and inclusively. Via YouTube, you can still view the ABC *Nightline* "Deep Dive" episode from 1999 for details on the IDEO designers' approach to solving the ill-structured shopping cart problem (Gearyinteractive, 2011).

Engineering design can also be applied to more well-defined problems. For instance, consider the highway repairs that are occurring all across the United States as cities and states work to maintain their transportation infrastructure. Civil engineers are often tasked with designing the set of materials, equipment, and processes that will be needed to repair a road. But for many roads, this is a well-defined problem that involves choosing from among a set of options rather than charting a new course to invent something unique. When a road needs to be repaired, the engineers already know how much wear and tear the road must sustain, how cold it gets in the winter, how hot it gets in the summer, how wide the road needs to be, what driving speeds it must support, and what materials the road surface currently contains. The engineering design task is to choose the correct combination of materials (e.g., gravel, asphalt, macadam) to repair this particular road surface and to plan the right sequence of heavy machinery to apply those materials safely and reliably. Because other engineers have solved this same general problem of road repair many times before, there is already a problem-solving path to follow, and any single instance of road repair is more like a well-defined problem than an ill-structured one.

Defining Engineering and Technology in General

Engineering design is just one activity—though a central one—within the enormous enterprise of engineering in general, which also includes activities of failure analysis, economics, ethics, aesthetics, communications, and quality control (ABET, 2021). Engineering has been informally practiced throughout history, but in recent centuries it has been formalized into professions and academic disciplines that rely heavily on math and science understanding (Seeley, 2005). Modern professional engineering companies work to make problem-solving products, systems, and analyses available to the public. Engineers work on many types of problems of different levels of complexity, ranging from very well-defined tasks, such as specifying the material for road repair, to highly ill-structured problems, such as improving the common shopping cart. In general, an engineer is anyone who applies creativity, empathy, and knowledge of mathematics and science to work on solutions to society's needs and wants (Burns & Leisseig, 2017; Walther et al., 2017; Wulf, 1998). These solutions are called *technologies*.

Technologies are the products that result from engineering work (Wulf, 1998). This means that everything from washable crayons to toothpaste to airplanes can be considered an example of technology. The early education and care field often uses the word *technology* as shorthand for *computer technology*—that is, when educators talk about children using technology, they tend to think of children and computers or some other digital device, such as a tablet computer, a smartphone, a television, or a camera. In this book, when we talk about the T in STEM, we are referring not only to these examples of computer technology but also to technology in general (i.e., all the tools and products that result from engineering, from pencils to robots). When children engage in emergent engineering, they might participate in creating technologies such as block towers that protect a pretend vegetable garden from hungry rabbits. They might also make use of existing technologies to scaffold their engineering activities. For example, a tablet computer might help them keep records of their different design ideas, or a specially designed nonslip surface might help them build with blocks more easily.

The Engineering Design Process

Engineers typically work together to solve the problems that face society. As mentioned earlier, engineering design is the process of creating solutions to human problems through creativity and the application of math and science knowledge. The fundamental practices within any engineering design process include at least the following six elements (Atman et al., 2007; Gibson et al., 2007; NGSS Lead States, 2013; WGBH Educational Foundation, 2011):

1. Defining a problem: Observing a problem, seeing a need for a solution, and identifying criteria and constraints
2. Researching possible solutions: Gathering information and coming up with ideas to address the problem
3. Choosing and planning the best solution: Conducting an analysis of plans and data to determine which idea might best address the problem
4. Building and testing a prototype: Constructing a working model of the chosen solution and investigating the working model to find out whether it solves the problem, holds up to any important tests, and follows any limits or rules imposed on the problem

5. Improving the design: Using evidence, comparing alternatives, and evaluating the ideas of peers to make adjustments until the working model solves the problem in a satisfactory way
6. Communicating the solution: Using oral and written language as well as tables, graphs, drawings, and models to express the solution to the problem and the advantages of the chosen solution

When engineering educators talk about engineering design practices, they are referring to ways of thinking and acting that are typical of adult engineers and that are productive for accomplishing engineering tasks (National Research Council [NRC], 2012). These practices do not occur in a regimented, consistent sequence of steps. They occur to different degrees and at different times within different engineering design processes. There is no single engineering design method (Lawson, 1997).

Even though there is no single engineering design method, many experienced engineers employ a common set of engineering design practices engineers (Cross, 2003). Engineers continually formulate and test hypotheses about the optimal solution to the problem they are trying to solve. They analyze and build models of potential solutions and clarify their understanding of the problem along the way. A strategy called *predictive analysis* is a tool used by engineers who are developing solutions that cannot be immediately built or tested owing to budget constraints, complexity of design, lack of information about the client's needs, or human safety, for example. Predictive analysis involves projecting how a proposed solution will behave before building and testing the solution itself. During predictive analysis, engineers estimate how many resources (e.g., time, money, fuel, raw materials) will be required to produce the solution, how successful it will be at solving the problem, how long it will last, and what impacts it might have on humans and the environment.

Once actually constructed or brought to the prototype stage, solutions often require further testing and experimentation to meet the criteria for success defined previously, and even the criteria for success may be amended as engineers and their collaborators progress through solving a problem. Issues of diversity, inclusion, equity, and justice need to be considered carefully before a solution is completed. For instance, engineers might learn as they test their design in new contexts that it works for some communities but not others. To ensure that their design is not discriminatory in its impacts, they need to expand their sense of what counts as a satisfactory solution (Benjamin, 2019). Engineers might also find out that although a design solves the original problem, the act of manufacturing or using that design unintentionally introduces a new problem. For example, a solar panel installation on a building roof may generate enough electricity to save the building owner in operating costs. But in the winter, its slick surface makes snow slide off the roof in one sudden avalanche, causing damage to the cars parked below. This new problem of snow sliding must be addressed, too, for the solar panels to count as a good design solution. Taking responsibility for either preventing or addressing new problems introduced by designs is an important part of practicing engineering with an "ethic of care," which requires not just technical skills but a great deal of moral reasoning as well (Riley, 2008, p. 111).

Responsible engineering is important because the results of engineering design processes have an impact on people in their everyday lives. Industrial, mechanical, and electrical engineers design the structures, systems, and machines that fill peoples' homes—including kitchen appliances, some furniture, heating and cooling systems, home lighting, televisions, music players, and computers. Every day, people use numerous substances perfected by chemical and biomedical engineers, including toothpaste, shampoo and conditioner, detergent, stain remover, plastics, bandages for cuts, and medicines. Vehicles are designed by teams of engineers from many disciplines, including mechanical, electrical, aerospace, and manufacturing engineering. The infrastructures of cities and towns—including municipal water systems, sanitation systems, roads, subways, bridges, tunnels, electricity delivery, traffic flow plans and traffic lights, skyscrapers, and airports—were all designed with the help of civil and environmental engineers. And of course computer engineers and computer scientists are behind the computer technology that now affects almost every arena of daily life.

OUR PROBLEM-SOLVING FRAMEWORK FOR EMERGENT ENGINEERING

This book emphasizes four phases of engineering design that are most appropriate for structuring young children's problem-solving activities: Think about it, Try it, Fix it, and Share it (see Figure 1.1). Together with the five thinking skills (described in

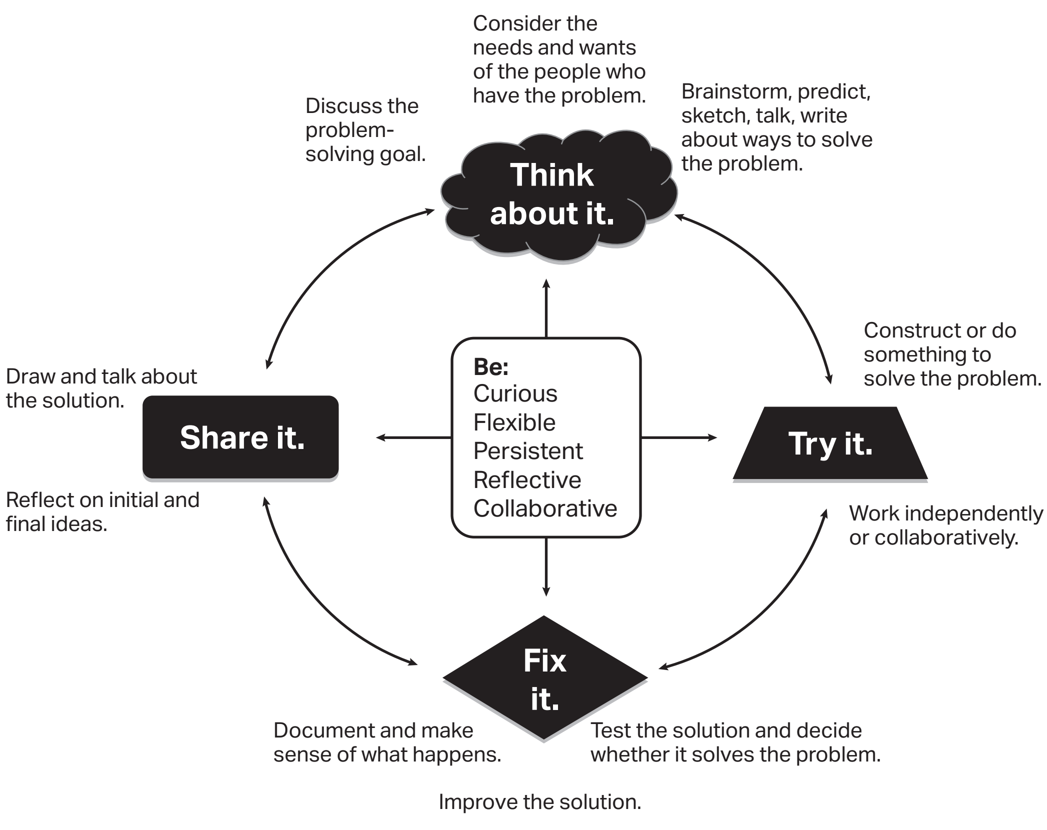

Figure 1.1. The phases and thinking skills of engineering design that make up this book's problem-solving framework for emergent engineering.

more detail later), the four phases make up our problem-solving framework for emergent engineering. Table 1.1 lists the tasks that children and adults carry out together in each phase and shows how those tasks correspond to the practices of professional engineers.

There are a few important caveats about the problem-solving framework. First, it is almost never developmentally appropriate—nor logistically feasible—for young children to conduct all four phases of the framework within a single sitting or activity. The phases are meant to help adults design units of learning rather than single experiences or lessons. However, by the same token, it is also typically not appropriate for young children to maintain a focus on only a single phase of problem solving during any one particular activity. In fact, professional engineers often implement several engineering design practices at the same time. It is not necessary, therefore, to design learning experiences that limit themselves to only one of the four phases.

There are several other approaches to focusing early childhood learning environments on the activity of problem solving, and our emergent engineering framework builds on these. We differ in the idea that children can be competent emerging engineers, and their problem-solving work can be in response not just to problems they have identified in their own daily activities but also to engineering problems that call for the application of creative thinking, mathematical reasoning, and scientific ideas. Our problem-solving approach using the emergent engineering framework could be incorporated into a Lillian Katz problem-based learning project or into a Reggio Emilia classroom, but the teacher would facilitate the children's enactment of an engineering design cycle to guide their work.

Figure 1.1 illustrates the phases and thinking skills of engineering design. We encourage you to use the vocabulary introduced in this framework while teaching.

Table 1.1. Phases and tasks within young children's engineering design

Phase of children's work	Tasks for children and adults	Engineering practices
Think about it	Talk, read, or listen about the problem. Discuss the goal for solving the problem. Identify the limits or "constraints" (e.g., number of materials, amount of time, size of structure) on solving the problem.	Identifying problems; unpacking requirements and constraints
	Look for similar problems and existing solutions. Discuss the needs and wants of the people who have the problem. Explore available materials. Make decisions about the problem-solving approach. ("We will build a boat instead of a bridge to solve the problem of crossing the river.")	Gathering information; revising the problem space
	Brainstorm. Design the solution to the problem. Model it. Predict how it will be carried out or built and how it will perform. Sketch, dictate sentences, and make other representations of how the solution might look and behave.	Modeling and analyzing potential solutions
Try it	Work collaboratively or independently with hands-on materials to "do" or "build." Take an action or construct an artifact that solves the problem. Materials can be blocks, recyclables, craft supplies, and so forth.	Prototyping
Fix it	Test out the action or artifact. Decide whether or not the action or artifact solves the problem. Document what happens during testing and what that means for the next version. Make changes to improve the solution.	Testing and analyzing prototype performance; iterating
Share it	Share the final action or artifact with children and adults. Draw and talk about it. Contribute to documentation panels. Reflect on initial ideas (brainstorms, sketches) and the final design and describe the differences between the two.	Representing and communicating about solution via multiple modes (e.g., drawings, text, speech)

Weaving engineering vocabulary into your practice not only supports children's development of STEM vocabulary and concepts, but it also reinforces the idea that your classroom is an engineering classroom—one where vibrant STEM learning takes place.

Thinking Skills for the Problem-Solving Framework

This book presents strategies for engaging young children in emergent engineering. To explain this idea of emergent engineering, it helps to draw an analogy to the field of emergent literacy. Early childhood educators and care providers know that most preschoolers and toddlers do not read entire books on their own from start to finish. However, even though young children do not often pick up a book and read it independently, adults do not wait until children are in first grade to start literacy learning experiences. Instead, from the infant stage on up, educators and care providers help children develop the book-handling, phonological-awareness, and letter-knowledge skills that will help them become readers. Researchers have uncovered and clearly defined the skills that are foundational for reading, and educators and care providers work to develop these skills through early literacy initiatives and activities. Even though the children cannot yet read on their own, educators and care providers do many things to include young children in the act of reading: read aloud to babies, toddlers, and preschoolers; give infants books to feel and taste and gaze at; and help preschoolers retell stories as they view illustrations.

Just as infants, toddlers, and most preschoolers are not developmentally ready to pick up a book and read it independently from start to finish, they are not quite capable of independently tackling a complex engineering design problem using all the phases of the problem-solving framework. Also, just as young children can be considered emergent readers, they can be considered emergent engineers who have many of the precursor skills that will be necessary to engage in independent engineering design later on. In fact, just as certain skills are required for reading literacy, certain skills are required for STEM literacy, and appropriately designed learning experiences can help develop STEM literacy skills, just as appropriately designed learning experiences can develop prereading skills. This book focuses on five thinking skills that are important for adult engineering, but just as important, they are skills exhibited by young children that can be extended and further developed through particular problem-solving experiences. The experiences presented in this book are designed to help children develop the foundational thinking skills for STEM problem solving; these skills also happen to be essential components of real-life engineering design. Infants are just acquiring these skills to begin to solve problems of reaching, grasping, and communicating nonverbally; toddlers are developing the thinking skills and applying them to many problems in the physical world; and preschoolers are nearing readiness for complex problem solving on their own.

What, then, are these foundational thinking skills for real-life engineering and young children's STEM problem solving? Studies of professional engineers have revealed that the enterprise of engineering draws on individuals' cognitive, sociocultural, and affective resources and that substantial growth occurs as engineers shift from novice to expert practice in design (Atman et al., 2007; Cardella et al., 2008; Cross, 2004). For instance, for engineers to plan possible solutions and revise solutions they have already tested, they need to engage in reflective decision making in collaboration with others (NRC, 2012; Schön, 1987). Rather than relying on random trial and error, engineers make decisions based on evidence about how well a design will work (NRC, 2012). To engage in reflective decision making in a collaborative way, people need tools for social interaction, including ways of communicating engineering ideas and ways of thinking like an engineer (Atman, Kilgore et al., 2008). Many of these ways of thinking overlap with the higher order thinking skills that should be fostered in young children. This book focuses on five thinking skills that overlap between engineering and young children's development: curious thinking, persistent thinking, flexible thinking, reflective thinking, and collaborative thinking. All the thinking skills come from our review of state standards for young children; they are the key skills that children from birth to age 5 need to learn at various levels of complexity. The following sections describe how engineers use each of these thinking skills and summarize the evidence of young children's development of each skill. This book's later chapters unpack each thinking skill in much more detail and describe what cognitive development research says about the thinking skills at each stage of growth from infancy to toddlerhood to the preschool years.

Curious Thinking

Engineers When determining the goals and constraints of a design problem, engineers consider broad, contextual issues, including social, logistical, environmental, and moral factors. For example, college engineering students working on a flood-control problem question the effects of possible design solutions on people and nature (Atman, Yasuhara et al., 2008). They ask not only who and what will be helped by this potential design, but also who and what might be harmed, and how might that harm be prevented (Nittala et al., 2021). Expert engineers working on a playground design problem consider legal liability, neighborhood opinions, and maintenance concerns (Atman et al., 2007), and they collaborate with people from the disability community to ensure that children of all physical abilities can play together.

Before beginning to plan and build solutions to design problems, expert engineers spend a substantial amount of time asking questions and gathering information about the problem (Atman et al., 2007). When engineers conduct predictive analyses, they use curious thinking to anticipate how possible solutions to problems might actually work.

Young Children Anyone who has spent time with infants and young children knows that they love to explore new objects and environments. And when they encounter a puzzle about what makes something work, they attempt to solve that puzzle through play (Gopnik, 2012). However, their love of exploration and questioning can be developed even further into a curious thinking habit of mind. For example, with encouragement to search for and observe insects in the school garden, toddlers can generate their own questions about insect behavior, such as how insects would respond to different surfaces and whether they sleep during the winter months when they cannot be found outside (Shaffer et al., 2009). In another example, when children are given a toy that only works one-third of the time it is activated, they develop ideas about what hidden variables might be responsible for the failures (Schulz & Sommerville, 2006).

Flexible Thinking

Engineers Experienced engineering designers know how and when to use a range of design strategies (Daly et al., 2012). They are flexible in altering their approach when necessary to deal with limitations of time and resources (Crismond & Adams, 2012). They must think creatively about how existing knowledge can be applied and combined in new ways (NRC, 2012). As they try out a prototype of a design solution, they find new information concerning how well it works, and they have to adjust their ideas according to this new information. Engineering problem-solving work requires great creativity and mental flexibility. These skills are especially crucial when engineers discover that a potential design might have disproportionate negative consequences on a particular community or part of the environment. And these skills are needed for the results of engineering to reflect the diversity of society.

Young Children Although young children sometimes perseverate on ideas and seem unlikely to ever relinquish their current thinking, cognitive science research has shown that young children can be quite flexible in their thinking when provided with enough evidence to accept new ideas (Gopnik, 2012). For example, in one study, 4-year-olds began by insisting that stomachaches could be not caused by psychological factors such as anxiety. However, as researchers presented the 4-year-olds with more and more evidence of psychologically caused illness, the children were more and more likely to give up their existing thinking and accept the new idea (Schulz et al., 2007). Similar research on children's social reasoning shows that children also have great capacity for flexible thinking in social situations. In light of new information from a trusted person, they can change their perspectives about other people and their intentions (Collaborative for Academic, Social, and Emotional Learning [CASEL], 2020).

Persistent Thinking

Engineers Iterative redesign is a universal feature of engineering (Petroski, 1996). Engineers make tweaks and cycle through repeated attempts at each phase of the design process, from refining their statement of the problem, to constructing dozens of prototypes, to proposing several options for materials selection and final specifications.

Another way that engineering designers are persistent is by purposefully holding multiple sets of requirements in their minds throughout a design process. They constantly refer to the physical principles that govern the design scenario, the wishes that their clients have expressed for an acceptable solution, and their own personal experiences with similar problems (Cross, 2003). It takes persistence to keep all these elements in mind throughout a problem-solving process.

Young Children As all early childhood educators know, classrooms of 3- and 4-year-olds can persist in solving the same problem (e.g., constructing ramps that keep cars from falling off them, moving water from one container to another using pumps) for many days—even weeks (Worth & Grollman, 2003). This persistent thinking is supported by their teacher's careful problem posing, provision of materials, and documentation (through photos, drawings, dictated texts, and anecdotal records) of children's questions and findings.

Reflective Thinking

Engineers An interesting contrast between recently graduated engineers and their more experienced colleagues is that the novices utilize a systematic trial-and-error approach to design: implement and evaluate each design idea through many iterations. By contrast, experienced engineers evaluate tentative design ideas before implementing them, thus engaging early in reflective decision making and spending their time implementing only potentially fruitful ideas (Ahmed et al., 2003). They also explicitly view evidence-based decision making as the cornerstone of engineering design (Daly et al., 2012). No matter what design process engineers follow, their activities always include analysis and testing of the work they are producing (Bucciarelli, 1994). When they have engaged in predictive analysis prior to prototyping and testing a solution, engineers use reflective thinking to compare their predictions with actual results.

Young Children Reflection can be described as "remembering with analysis" (Epstein, 2003, p. 2). For young children, remembering involves recalling both what they planned to do and what they did. Analysis by young children answers the question "How did it go?" When children are guided to plan, carry out, and reflect on their own learning activities, they show more purposeful behavior and more success on intellectual measures (Sylva, 1992).

Collaborative Thinking

Engineers Informed engineering designers are effective group collaborators (Crismond & Adams, 2012). In fact, the ability to function well in teams is a requirement of college-level engineering education programs (ABET, 2021). Engineering professors often assign team design projects to help students improve their skills in teamwork, communication, and collective decision making (Borrego et al., 2013). These professors know that engineering is a collaborative endeavor and that successful practicing engineers engage often in the communication tasks of translation, clarification, negotiation, and listening (Darling & Dannels, 2010).

Young Children In an example of a natural setting where children engage collaboratively with an engineering challenge, Worth and Grollman (2003) describe a preschool classroom where so many children were engaged in the challenge of making balls travel as far as possible down cardboard ramps that their teachers grouped them into teams of four children each; each team had either all 3-year-olds or all 4-year-olds. The teacher noted that although the 3-year-olds proceeded by carrying out trial-and-error methods together, the 4-year-olds truly collaborated by suggesting ideas to each other, trying them out, and communicating lessons learned to incorporate into their next ramp system. Being a contributing member of a team is a skill that can be learned. When encouraged to reflect on and listen to their peers' recommendations, elementary school students critiqued each other's engineering designs in ways that led to substantive changes in their products (Capobianco et al., 2011).

THE PROBLEM-SOLVING FRAMEWORK, CHILD DEVELOPMENT, AND STANDARDS OF EARLY EDUCATION AND CARE

Different theories of children's cognitive and social-emotional development call for different approaches to the creation of learning experiences. Our emergent engineering approach, grounded by the five thinking skills and the "think about it, try it, fix it, and share it" cycle, reflects the view that young children's development is a back-and-forth process in which the social and cultural context strongly influences a child's intellectual and emotional growth. Children's innate cognitive abilities, social-emotional skills, and perceptions all interact with the people and objects around them at any given time, and different areas of knowledge and different skills emerge in different contexts. This is why the different activities in this book foster different kinds of thinking skills and different parts of the engineering design cycle.

Our view of child development draws from several key theories of cognitive and social-emotional development. The first is Piaget's constructivist idea (1954) that children construct new knowledge through interactions with objects in their environment. For this reason, all our emergent engineering activities call for children to solve problems with physical objects and materials. Piaget's constructivist idea was elaborated by Vygotsky's theory that children's knowledge construction is influenced strongly by conversation with more knowledgeable adults (1962). With the tool of language, adults help children articulate the abstract concepts they are constructing in their minds through their play and exploration of the world. As a result, all our emergent engineering activities place a strong emphasis on adults' use of language to interpret, elaborate on, and raise questions to children about their problem-solving work and play. We also propose activities that at times seem just beyond children's reach. We do this intentionally, because with the careful guidance of adults, children can stretch their skills to accomplish new tasks and then develop the skills needed to carry out those tasks on their own. This aspect of the emergent engineering framework relies on Vygotsky and Cole's (1978) notion that children have a zone of proximal development where adults can offer scaffolding to enable children to carry out higher mental processes that they would not be able to do alone. Of course, the zone of proximal development is only open when children trust the adult who is offering support, and so emergent engineering activities also call for adult caregivers to be responsive to young children's needs and to intentionally serve as a secure base from which children can explore. The notion that attachment networks (Howes, 1999) are essential to both intellectual and social-emotional development is important to the work in this book. Finally, to help children reach their potential as emergent engineers, we have designed activities that are inspired by Fischer and colleagues' (1993) portrayal of children's competence not as a characteristic of an individual child but as an attribute of that child in context. The problem-solving experiences in Chapters 3 through 7 of this book provide rich, meaningful contexts in which children can explore big ideas and exercise higher order thinking skills to accomplish engaging tasks. These contexts allow children to demonstrate competence that often far exceeds what adults first thought possible for them.

Standards of early education and care also support this book's claim that young children can develop the five thinking skills of emergent engineering. In fact, the learning goal of becoming a curious, persistent, flexible, reflective, and collaborative thinker is reflected in the Next Generation Science Standards (NGSS Lead States, 2013) and the Common Core State Standards for Mathematics (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010), as well as in early childhood learning outcomes documents for several states, including California, Ohio, and Massachusetts. Table 1.2 shows how standards for early education and care from these national and state documents align with each of the five emergent engineering thinking skills. The learning activities in this book can help infants, toddlers, and preschoolers meet these standards and others as they take delight in becoming young engineering problem solvers.

Table 1.2. Alignment of the emergent engineering thinking skills with standards for early education and care

	Curious thinking	Persistent thinking	Flexible thinking	Reflective thinking	Collaborative thinking	Web link
Massachusetts Guidelines for Infants and Toddlers (Massachusetts Department of Early Education and Care, 2011)	SED19. The young infant explores the environment around them. SED22. The older infant more actively explores the environment.	CD12. The young infant repeats a pleasing sound or motion. CD13. The young infant discovers that repeated actions yield similar results. CD14. The older infant closely observes actions and discovers that repeated actions yield similar results. CD15. The older infant performs an action to get a resulting event to occur.	CD30. The young infant begins to learn how objects work by handling them and watching others use them. CD31. The older infant actively explores the environment to make new discoveries.	CD24. The young infant becomes aware of patterns in the environment. CD28. The older infant begins to recognize patterns.	LC8. The young infant understands and uses social communication. LC9. The older infant begins to comprehend and use social communication.	http://www.eec.state.ma.us/docs1/Workforce_Dev/Layout.pdf
California Infant Toddler Desired Results (Center for Child and Family Studies, 2010)	COG6: Curiosity	COG7: Attention maintenance	COG2: Problem solving	COG1: Cause and effect	SSD13: Social understanding	http://www.desiredresults.us/docs/Forms%20page/DRDP%20(2010)/IT%206_29_10F.pdf
Massachusetts Preschool Guidelines (Massachusetts Department of Education, 2003)	Science and technology, Inquiry Skills 1. Ask and seek out answers to questions about objects and events with the assistance of interested adults.			Science and Technology, Inquiry Skills 4. Record observations and share ideas through simple forms of representation such as drawings.	Science and Technology, Inquiry Skills 4. Record observations and share ideas through simple forms of representation such as drawings.	http://fcsn.org/pti/topics/earlychildhood/preschool_learning_eec.pdf
Massachusetts Preschool STEM Standards (Massachusetts Department of Elementary and Secondary Education, 2014)	Observe and ask questions about observable phenomena (objects, materials, organisms or events).		Construct theories based in experience about what might be going on. (PreK-LS2-2). Look for and describe patterns and relationships (PreK-LS1-2 PreK-LS1-3).	Support thinking with evidence. Engage in discussion before, during and after investigations.	Document experiences and thinking to communicate with others.	http://www.mass.gov/edu/docs/eec/2013/20131009-pk-sci-tech-standards.pdf

California Preschool Learning (California Department of Education, 2010)	COG4: Curiosity and initiative	COG5: Engagement and persistence	COG2: Problem solving	COG1: Cause and effect	LLD3: Expression of self through language	http://www.cde.ca.gov/sp/cd/ci/documents/drdp2010preschooleng.pdf
Ohio Early Learning Content Standards (Ohio Department of Education, 2012)	Approaches to Learning: Initiative and Curiosity	Approaches to Learning: Engagement and Persistence	Approaches to Learning: Innovation and Invention	Approaches to Learning: Planning, Action and Reflection	Social and Emotional Development; Peer interaction and relationships	http://education.ohio.gov/Topics/Early-Learning/Early-Learning-Content-Standards/The-Standards
Head Start Child Outcomes (Office of Head Start, 2011)	Approaches to Learning: Initiative and Curiosity	Approaches to Learning: Persistence and Attentiveness	Approaches to Learning: Reasoning and Problem Solving		Approaches to Learning: Cooperative	https://eclkc.ohs.acf.hhs.gov/hslc/tta-system/teaching/eecd/Assessment/Child%20Outcomes/HS_Revised_Child_Outcomes_Framework(rev-Sept 2011).pdf
Common Core State Standards for Mathematics (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010)	Standards for Mathematical Practice, 1. Make sense of problems and persevere in solving them.	Standards for Mathematical Practice, 1. Make sense of problems and persevere in solving them.	Standards for Mathematical Practice, 2. Reason abstractly and quantitatively.	Standards for Mathematical Practice, 3. Construct viable arguments and critique the reasoning of others.	Standards for Mathematical Practice, 3. Construct viable arguments and critique the reasoning of others.	http://www .corestandards.org/ assets/CCSSI_Math%20Standards .pdf
Next Generation Science Standards for Kindergarten (National Research Council, 2012)	With guidance, plan and conduct an investigation in collaboration with peers. (K-PS2-1)	Use observations (firsthand or from media) to describe patterns in the natural world in order to answer scientific questions. (K-LS1-1)	Use tools and materials provided to design and build a device that solves a specific problem or a solution to a specific problem. (K-PS3-2)	Analyze data from tests of an object or tool to determine if it works as intended. (K-PS2-2)	With guidance, plan and conduct an investigation in collaboration with peers. (K-PS2-1) Construct an argument with evidence to support a claim. (K-ESS2-2) Communicate solutions with others in oral and/or written forms using models and/or drawings that provide detail about scientific ideas. (K-ESS3-3)	http://www.nextgenscience.org/sites/ngss/files/k%20combined%20DCI%20standards%206.13.13_0.pdf

EDUCATION / PRESCHOOL & KINDERGARTEN

"Provides excellent examples of high-quality STEM activities to support children's problem-solving and critical thinking skills...a great resource for early childhood educators in inclusive settings."

—Serra Acar, Ph.D., Assistant Professor, University of Massachusetts Boston

Boost young children's problem-solving skills and set them up for long-term success with the second edition of this practical guidebook! Enhanced with new lessons and timely topics—including equity and the use of makerspaces—this book will help you get all children ready for kindergarten by teaching them basic practices of engineering design and critical thinking skills. Using a clear instructional framework and fun lesson plans tailored for infants, toddlers, and preschoolers, you'll guide your "emerging engineers" as they explore big ideas and develop new ways of thinking through engaging and challenging learning experiences.

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