Engaging Young Engineers

Teaching Problem-Solving Skills Through STEM

by

Angi Stone-MacDonald, Ph.D.

Kristen Wendell, Ph.D.

Anne Douglass, Ph.D.

and

Mary Lu Love, M.S.

University of Massachusetts Boston

PAUL H. BROOKES PUBLISHING CO.®

Baltimore • London • Sydney

Paul H. Brookes Publishing Co.
Post Office Box 10624
Baltimore, Maryland 21285–0624

www.brookespublishing.com

Typeset by Scribe Inc., Philadelphia, Pennsylvania.
Manufactured in the United States of America by
Sheridan Books, Inc., Chelsea, Michigan.

The individuals described in this book are composites or real people whose situations are masked and are based on the authors' experiences. In all instances, names and identifying details have been changed to protect confidentiality.

Photographs are used by permission of the individuals pictured and/or their parents/guardians.

Cover image © istockphoto/CEFutcher
Photographs in Figures 3.3, 3.4, 4.4, 6.3 and on pages 126 and 155 by Kristen Wendell. All other photographs by K.A. MacDonald (www.kamacdonaldphoto.com).

Library of Congress Cataloging-in-Publication Data

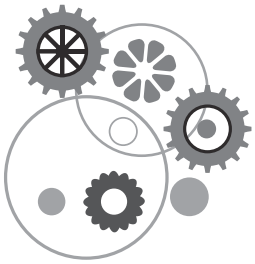
The Library of Congress has cataloged the print edition as follows:

Library of Congress Cataloging-in-Publication Data
Stone-MacDonald, Angela
Engaging young engineers : teaching problem solving skills through stem / Angi Stone-MacDonald, Ph.D., Kristen Wendell, Ph.D., Anne Douglass, Ph.D. and Mary Lu Love, M.S., University of Massachusetts Boston.
pages cm
Summary: "This title provides instruction on how to teach problem solving and critical thinking to young children (birth to 5) using engineering, science, and routines as a framework. The engineering process is an ideal framework for designing learning experiences that support science, technology, engineering, and mathematics (STEM) learning and cognitive development for young children. Young children problem-solve in their daily play, and teachers and caregivers can promote the development of problem solving and critical thinking skills through intentional activities that support young children's brain development and prepare them for kindergarten. Key activities are outlined for each age group, with information on how each activity teaches young children to be curious, persistent, flexible, reflective, and collaborative. This title also provides specific guidance for supporting problem solving and science learning in inclusive classrooms using the universal design for learning (UDL) model, and it helps teachers to prepare children to work towards the Common Core State Standards (CCSS) for kindergarten math and the Next Generation Science Standards (NGSS) for kindergarten science. This title can serve as a supplemental text for early childhood curriculum or instructional methods courses" —Provided by publisher.
ISBN 978-1-59857-653-5 (paperback) — ISBN 978-1-59857-849-2 (retail pdf) — ISBN 978-1-59857-846-1 (retail epub)
1. Science—Study and teaching (Early childhood)—United States. 2. Technology—Study and teaching (Early childhood)—United States. 3. Engineering—Study and teaching (Early childhood)—United States. 4. Mathematics—Study and teaching (Early childhood)—United States. I. Stone-MacDonald, Angela II. Title.
LB1139.5.S35S86 2015
507.1—dc23 2015000368

British Library Cataloguing in Publication data are available from the British Library.

2019 2018 2017 2016 2015

10 9 8 7 6 5 4 3 2 1



Contents

About the Forms vii
About the Authors ix
Foreword *Marilou Hyson* xi
A Note to the Reader xiii
Acknowledgments xxi

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

1 Young Children Are Natural Problem Solvers: A Framework Overview 3
2 Universal Design for Learning to Support Engineering Experiences in Inclusive Early Childhood Settings 21

II Using the Problem-Solving Framework to Teach Thinking Skills in Inclusive Early Childhood Settings

3 Curious Thinkers 39
4 Persistent Thinkers 63
5 Flexible Thinkers 87
6 Reflective Thinkers 111
7 Collaborative Thinkers 133
8 Curious, Persistent, Flexible, Reflective, and Collaborative Teachers 155

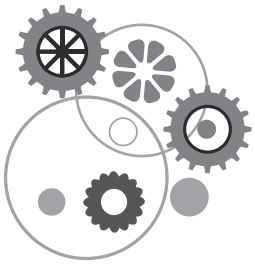
References 165

Appendixes 173
Appendix A Early Childhood UDL Planning Sheet: Infants (Sample) 175
Appendix B Early Childhood UDL Planning Sheet: Toddlers (Sample) 176
Appendix C Early Childhood UDL Planning Sheet: Preschoolers (Sample) 177
Appendix D Early Childhood UDL Planning Sheet: Blank 178
Appendix E Infant Experience Planning Template 179
Appendix F Toddler Experience Planning Template 180
Appendix G Preschool Experience Planning Template 181

Index 183

8

Curious, Persistent, Flexible, Reflective, and Collaborative Teachers



This book has focused on two big ideas. The first is that young children can be emergent engineers. As described, preschoolers, toddlers, and even infants exhibit many of the foundational skills used in the complex problem-solving activity of engineering design. Furthermore, teachers and caregivers can support and foster the development of young children's problem-solving skills. The second big idea in this book is that children's emergent engineering activities can further develop their higher order thinking skills and at the same time provide an exciting context for integrated STEM learning in the early years. Previous chapters presented strategies for teaching curious, persistent, flexible, reflective, and collaborative thinking with very young children using a universal design approach. We have shown how applying this problem-solving framework promotes STEM learning and development among all young children and also enhances learning across the curriculum in areas such as language and literacy, approaches to learning, and the domain of social and emotional development.

This final chapter deepens the potential impact of these engineering design experiences by applying our framework and the five higher order thinking skills to the adults and the broader classroom or early learning context. Most of this book has focused on children's thinking. Implementing early learning experiences such as those presented in this book provides rich opportunities for young children to develop their emerging engineering and higher order thinking skills. Now the approach is extended to focus on adult thinking. It is not enough to just plan discrete activities for children to develop their thinking skills. Adults must continually develop and model their use of higher order thinking skills and do so in ways that are visible to children.

Research shows that children's learning can be greatly enhanced when the overall learning environment and the adults in this environment reflect, model, and demonstrate higher order thinking skills in everyday routines and interactions. This chapter examines *teachers'* curious, persistent, flexible, reflective, and collaborative thinking and suggests concrete strategies for incorporating, extending, and modeling these higher order thinking skills in classrooms and other early learning environments.

The five thinking skills presented in this book are important professional competencies for educators. The widely used Classroom Assessment Scoring System (CLASS) identifies each of these skills as key components of high-quality teaching (Pianta, La Paro, & Hamre, 2008). For example, asking questions, wondering (curiosity), and being persistent are identified as high-quality teaching behaviors that promote young children's concept development. The code of ethics of both the NAEYC and the DEC of the Council for Exceptional Children call for educators to establish and maintain collaborative relationships and to consistently engage in reflective practices (Division for Early Childhood, 2009; Feeney, Freeman, & Pizzolongo, 2012).

Curiosity, persistence, flexibility, reflection, and collaboration can also be thought of as teaching dispositions. A *disposition* is a "value, commitment, or an ethic that is internally held and externally demonstrated" (Cudahy, Finnan, Jarusiewicz, & McCarty, 2002). Dispositions are often defined as habits of mind and action. Together, these thinking skills and habits represent a professional disposition toward lifelong learning. Many consider lifelong learning to be a core component of professionalism in teaching (Stremmel, 2007). Educators of young children learn with and from children in a joint process of inquiry. Their curiosity about how children learn and make sense of the world guides them to carefully observe and record children's behaviors. They reflect on these observations and explore ways to extend each child's learning and development through intentional and deliberate teaching practices and interactions. When they encounter challenges, they do not give up—on themselves, their colleagues, children, or families. They persist in seeking new solutions to ensure that all children and families have opportunities for growth, learning, and joy. Educators know that collaboration with families and colleagues is essential to their ability to be effective in this process.

This cycle of professional practice reflects an inquiry stance and a commitment to lifelong learning. It is important to nurture and support this curiosity, persistence, flexibility, reflection, and collaboration professionally and among co-workers for two primary reasons:

1. *To solve teaching challenges* by strengthening themselves as lifelong learners and problem solvers who are equipped to support the development of all young children
2. *To model problem-solving* in order to support and deepen the development of children's thinking skills

Next, each thinking skill is described and applied to adults in the context of teaching young children from birth to age 5. Then the final section of this chapter illustrates strategies teachers can use in applying this problem-solving framework to everyday problems they face.

CURIOUS TEACHERS

We have learned that curiosity fuels learning and exploration among children and is an essential foundation for cognitive development and science learning. Curious thinking is just as important for teachers. A curious teacher is best defined as a teacher who asks

Curious Teachers . . .

- Wonder aloud
- Ask open-ended questions
- Talk with excitement about learning and exploring

questions and wonders. Curiosity fuels effective teaching by motivating us to ask questions and seek new solutions. Professor Andrew Stremmel writes, "Teaching is a process involving continual inquiry and renewal, and a teacher, among other things, is first and foremost a questioner" (2007, p. 1).

When teachers demonstrate and model curiosity, they create learning environments that value and nurture children's curiosity. These are learning environments filled with excitement, exploration, and imagination. In high-quality classrooms, teachers consistently demonstrate curious thinking by asking open-ended questions and wondering. Research affirms that these practices support children's thinking and concept development (Pianta, La Paro, & Hamre, 2008).

PERSISTENT TEACHERS

Persistence is an essential disposition for early educators, especially when working with children with special needs or challenging behaviors. Educators know that teaching young children is complex and that one approach or strategy will not work with every child. Persistent educators hold high expectations for all children. They do not give up when their first strategy for engaging a child does not work. They stick with it and keep trying new strategies until they are successful. When teachers of young children use persistence, they engage with a child "in a sustained back and forth exchange with the intention of helping him or her really understand ideas or get to the correct answer. The teacher persists in these efforts rather than just stopping with one clarifying comment" (Pianta, La Paro, & Hamre, 2008, p. 73). This is the essence of persistence and of high-quality teaching practices.

When teachers model persistence, take risks, and try a new approach in the face of a challenge, they foster the development of persistent thinking. Teachers can model several key lessons about persistence; for example, 1) persistence means trying again and often trying a new or different approach, and 2) persistence can result in improvement and success. Persistence also relies heavily on another thinking skill in our problem-solving framework: reflection. Persistence and reflection go hand in hand. When teachers try again and again, they do not just repeat the same approach over and over. They reflect on their approach to inform their next attempt.

Persistent Teachers . . .

- Do not give up
- Believe they can succeed and believe every child can succeed
- Seek out alternative approaches and solutions
- Learn from prior attempts

Flexible Teachers . . .

- Are open-minded
- Consider new and different ideas
- Change direction or course as needed
- Are willing to take a risk

FLEXIBLE TEACHERS

Flexible thinking is the hallmark of effective early childhood educators. They must adapt and improve daily when their best planning and intentions get disrupted by the unexpected. An outdoor drama activity must suddenly get moved indoors when a storm arrives. An elaborate cooking activity must be adapted when the oven decides to quit. Another dimension of flexible thinking is the awareness that there is almost always more than one way to solve a given problem.

So how can educators model this flexible thinking in ways that enhance children's thinking? One way that teachers model flexibility is by thinking out loud as they adapt a planned outdoor activity to an indoor one. When a teacher says what he or she is doing or thinking, this is sometimes referred to as "self-talk," a high-quality teaching practice described by Pianta, La Paro, and Hamre (2008) as a strategy for modeling and promoting language development. Another way that teachers demonstrate flexible thinking is by allowing children to suggest many possible responses to a question or a problem rather than looking for just one answer.

REFLECTIVE TEACHERS

Reflection means that teachers must step back from their practice and make time to ask questions and wonder. Reflective thinking can be considered on three levels: reflection *on* action, reflection *in* action, and reflection *for* action (Killion & Todnem, 1991; Schön, 1983, 1987). Teachers reflect *on* their practices when they think about and talk about why an interaction or a lesson did or did not go as planned. They reflect *in* action when they take a moment to think during a situation or interaction with children. When they do this and then adapt or modify their actions to get the response they want from children, they are reflecting in action (Thomas & Packer, 2013). Teachers reflect *for* action when they think and talk about how to prepare for an action or interaction. Reflection is the process that informs how educators differentiate and adapt their teaching for individual learners. In diverse and inclusive classrooms, differentiated instruction and implementation of UDL supports are essential for engaging and supporting each individual learner.

Reflective Teachers . . .

- Take time to pause and think about their teaching practices
- Observe and take notes
- Wonder why an activity or interaction did or did not go as planned
- Notice and adapt based on prior experiences

Teachers reflect regularly. Reflection can come to be a natural part of the teaching process. Yet often they reflect in private or only with other adults. Children often do not know how or when their teachers reflect. How can teachers make reflection more visible to children in ways that model this thinking process? One way is to think and wonder out loud, as suggested for flexible thinking. For example, share with children that you noticed how much they liked the book you read yesterday about fire engines. Now you are wondering if they might be interested in visiting the local fire station or inviting a firefighter to visit the class. When a teacher takes notes about an experience to refer to later when evaluating the experience, he or she can share this reflective process with children, making it visible to them.

COLLABORATIVE TEACHERS

When teachers think collaboratively, they engage with others to achieve a shared goal. Therefore, the foundation for collaboration is the presence or development of a shared goal. In the complex work of teaching, collaboration with colleagues enables teachers to reflect and inquire together about problems and challenges in order to develop new approaches and solutions. Sometimes this collaboration involves multidisciplinary teams coming together to share, reflect, and plan for how to support an individual child. Other times, members of a teaching team meet to think together about how children are learning in their classrooms and how to modify, adapt, and expand their teaching to extend that learning.

Research confirms that these teacher collaboration processes are associated with teacher learning and improved teaching practices (Hord, 1997; Nelson & Slavit, 2008). Learning together with other teachers about how to improve teaching can be one of the most rewarding and professionally enriching aspects of our work.

APPLYING THINKING SKILLS TO PRACTICE

The problem-solving framework, with its five thinking skills, will now be applied to two teaching scenarios. This use of the problem-solving framework is demonstrated for two purposes: first, to solve a teaching challenge, and second, to model problem-solving thinking for children.

1. *Solving a teaching challenge:* A typical teaching problem illustrates how a teacher applies these thinking skills to his or her practice.

Collaborative Teachers . . .

- Make time to talk, share, and learn with others
- Establish shared goals with others
- Demonstrate respect for differing perspectives and ideas
- Value collaborative problem solving

Mariela, a preschool teacher, has noticed that 3-year-old Cassie consistently avoids drawing and writing. Mariela is concerned that Cassie's resistance to drawing will interfere with her development of important school readiness skills. How can Mariela use the five problem-solving skills as a teacher to figure out how to support Cassie's learning?

During this school year, Mariela has tried several different approaches she previously used with other children to engage Cassie in drawing activities. Despite these repeated attempts, Cassie still refuses to participate in any drawing or writing activities. When pushed, Cassie becomes upset and refuses to talk or participate in any activity for a period of time.

Mariela becomes curious—she wonders why Cassie avoids drawing. All the other children in the class regularly engage in these kinds of activities and seem to enjoy them. They "sign" their names on the white board upon arrival in the morning and sit at the writing center table drawing pictures during activity times.

Mariela reflects on what Cassie chooses to do most often and how Cassie has responded in the past when encouraged to use drawing materials. Mariela shares her concerns at a collaborative teaching team meeting. The teachers all decide to keep observational notes this week in response to the questions about Cassie. One of the teachers suggests they ask Cassie's family about her drawing experiences at home, and they all agree this will be helpful information.

At the next week's meeting, the teachers share their notes. They are fascinated to learn that Cassie in fact did engage in a writing activity that week. Cassie spent most of her time playing dress-up in the dramatic play area. Another child brought a pad of paper and markers to the area to make a shopping list that week, and Cassie started writing a list of her own. However, Cassie's parents reported that she does not seem to have an interest in drawing at home.

Teachers brought Cassie's shopping list to their meeting. They reflected collaboratively on Cassie's writing. One teacher suggested that Cassie might be more motivated to write when she is with peers in the context of an activity that is meaningful. They then generated a list of new strategies for engaging Cassie in drawing and writing, all building on Cassie's demonstrated interest in writing in the context of dramatic play activities. Table 8.1 summarizes how Mariela applied the five thinking skills to solve a problem in her practice.

2. *Modeling problem-solving for children:* The second scenario illustrates how teachers can model the problem-solving process and make it visible to children.

Pierre, a teacher of toddlers, is confronted by a problem on the playground one day. One of the three tricycles has a broken wheel, and he has a class of eight toddlers who all want

Table 8.1. How Mariela used problem-solving skills: The case of Cassie's writing

Curious	Persistent	Flexible	Reflective	Collaborative
• Wondered about Cassie's behavior • Wondered how Cassie was at home	• Tried multiple strategies to engage Cassie • Believed that Cassie could succeed	• Was open to generating new approaches to try • Was willing to follow Cassie's lead	• Took observational notes • Reviewed and evaluated prior efforts to engage Cassie	• Met with the team to discuss • Pooled knowledge and insights with the team • Learned that Cassie was writing with her peers

to ride the tricycles today. How can Pierre model his use of the five problem-solving skills in ways that are visible to the children?

Pierre wants to get the broken tricycle fixed and back into use as soon as possible, but he also sees an opportunity to model critical problem-solving skills with the toddlers. With the toddlers all standing around inspecting the broken tricycle, Pierre calls to his coteacher, Amanda, to show her the problem. He asks her if they have a screwdriver to reattach the wheel to the tricycle. Amanda replies that the screwdriver has recently gone missing. The children look worried.

Pierre promises the children that he will not give up. He wonders aloud: "How can we fix the wheel without a screwdriver?" He says he thinks maybe a quarter would work. He pulls one out of his pocket and tries to use it to turn the screw, but the quarter is too thick. He explains that he will need to adapt his approach and try something else. He asks Amanda and the children if they can think of any other items that might work similarly to a screwdriver, with a hard, straight, thin edge. They generate several different ideas: a dime, a small pair of scissors, or a key. Pierre thinks out loud: "So we have a couple of possible other tools we can try. Let's try one at a time and figure out if any of them will work to screw this wheel back on."

They gather the other possible tools, and after several attempts, the dime works to screw the wheel back on securely. Pierre reflects aloud: "I wasn't sure if we were going to be able to fix this without the screwdriver. But we kept trying until we fixed it with the dime. You all really know how to help solve a problem." Table 8.2 summarizes how Pierre applied the thinking skills in this scenario.

These two problem-solving scenarios illustrate how individual teachers applied the problem-solving framework. However, creating a problem-solving culture in early childhood programs requires the involvement of not only individual teachers but also program leaders and the community of teachers. Early childhood programs can create an organizational culture that supports and fosters teachers'—and children's—problem solving. Research shows that the organizational context in which teachers work (i.e., the classroom, program, or school) influences teachers' behaviors and practices (Douglass, 2011; Nelson & Slavit, 2008). Think about a work environment in which new ideas are welcomed, teachers feel safe asking questions and wondering with colleagues and supervisors about teaching challenges, and leaders actively support and reward these inquiry processes. This is an environment that supports collaborative problem solving, creating a safe space for inquiry, reflection, and adaptation of teaching practices to achieve desired outcomes. This chapter can be used in staff training as a tool for dialogue about how to support an inquiry approach to teaching in your own program or school.

Table 8.2. How Pierre demonstrated the problem-solving skills: The case of the broken tricycle

Curious	Persistent	Flexible	Reflective	Collaborative
• Wondered aloud what other tools might substitute for a screwdriver	• Did not give up • Believed that they could find a solution to the problem	• Asked for help • Tried different new ideas	• Thought out loud about each attempt • Explained his thinking process and how it resulted in success	• Asked for ideas and suggestions • Shared joy at their collective success

CONCLUSION

Children's learning of the thinking skills needed for problem solving and engineering design can be maximized by applying a problem-solving framework to teaching. Through enriching and inclusive learning experiences and modeling of our own problem-solving processes, all children can develop as curious, persistent, flexible, reflective, and collaborative learners. Often teachers draw upon these thinking skills when responding to challenges they face as teachers. This chapter identifies specific ways teachers can apply the problem-solving framework to problems they face. Furthermore, this chapter argues that teachers must make these thinking processes visible to children so that they model the use of higher order thinking skills in ways that can extend children's learning.

The problem-solving framework presented in this book is a powerful resource for promoting higher order thinking skills. Both adults and children, including infants, develop and practice these thinking skills in the context of supportive learning environments and relationships. Teachers plan learning experiences, such as those described in this book, that engage children's curiosity and foster their thinking processes. In addition, teachers look for opportunities in their day-to-day work to model their own use of problem-solving skills when encountering challenges. In doing so, they create an environment that stimulates and nurtures young children as problem solvers and emerging engineers.