The Use of Literacy Routines as a Bridge to STEM Lessons

P. Renee Hill-Cunningham, Jerilou J. Moore
University of Mississippi
USA

Abstract

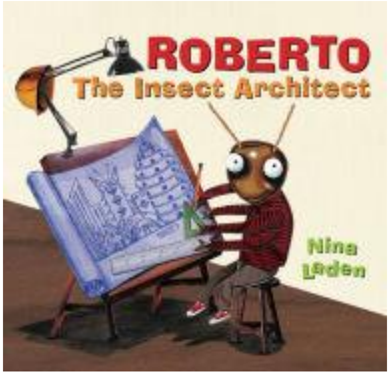
Elementary teachers are familiar with using literature and questioning techniques in teaching literacy. The good news is they can apply the same skills to teach STEM lessons. STEM instruction, particularly engineering, in elementary schools is virtually non-existent. However, using design challenges based off of children's literature can open up a new avenue to teach higher-order thinking. The use of literature with STEM foci, and "queries," questions that get at in-depth answers, can bridge teachers' comfort levels with STEM lessons, building students' creativity, curiosity, and perseverance.

STEM Education and literacy are a perfect match: excellent children's books support literacy skills, and also introduce children to topics in science, technology, engineering and math. Even more importantly, STEM and literacy connect through inquiry and critical reading. Critical reading is not only about what the text says, but the interpretation of the text and the construction of meaning. This involves higher levels of thinking where students are actively engaged in the analysis of information. Inquiry too, requires students to be actively engaged in interpreting data and the construction of new knowledge. Thus, both require students to construct meaning from information. If these two connect so well, why are they not integrated together in elementary classrooms?

Using Children's Literature

The mention of STEM education implementation evokes different responses in elementary classroom teachers. Sometimes, it is excitement, but many times, it is fear. Finding a way to bridge STEM with a familiar instructional routine will make its implementation more satisfactory. Elementary teachers, especially teachers of grades kindergarten through three, are familiar with integrating children's literature selections or trade books in their lessons. The more comfortable teachers are with the process they use to teach a concept, the more successful the lesson will be. Since teachers use picture books frequently as a springboard to a lesson, it is logical to use them to introduce STEM concepts.
Jumpstarting STEM lessons with picture books is helpful for elementary teachers to have a level of familiarity as they teach new concepts. Elementary teachers have vast experiences in choosing picture books to supplement basal reader selections, and teaching a theme topic such as civil rights. This knowledge of picture books can apply to any topic, concept or content. An example of this would be, *Roberto, The Insect Architect*, by Nina Laden, highlighted in Figure 1.

Figure 1. Cover for *Roberto, The Insect Architect* by Nina Laden (2009).



This picture book is an obvious STEM link, as architects fall under the *Engineering* part of the STEM umbrella. Stories that have a nature storyline, like Janell Cannon's, *Stellaluna*, or a story where something floats, like Oscar's costume in Dav Pilkey's *Hallo-Weiner* can link with science lessons, and can be the impetus for design challenges. For mathematics, Cindy Neuschwander's book, *Sir Cumference and the First Round Table*, uses geometry to find the perfect shape for King Arthur's knights' meeting table. In *Dot* by Randi Zuckerberg, Dot uses her technology skills to find lots of information. Using these picture books and others (see Figure 2), to integrate and enhance learning of concepts is a familiar and effective way to teach. Making the connections between the concepts and the picture books requires students to use their own prior knowledge and higher order thinking skills.

Figure 2: Examples of Picture Books to Integrate with STEM

Picture Books	**Author**	**Topic/Concepts**
Roberto, The Insect Architect	Nina Laden	Engineering/Architecture
Stellaluna	Janell Cannon	Science/Nature
Halloweiner	Dav Pilkey	Science/Floating
Sir Cumference and the First Round Table	Cindy Neuschwander	Mathematics/Geometry
Dot	Randi Zuckerberg	Technology/Information
What Color is My World	Kareem Abdul-Jabbar	Engineering/Inventions
Marvelous Mattie	Emily Arnold McCully	Engineering/Inventions
Rosie Revere Engineer	Andrea Beaty	Engineer/Flight
Love Flute	Paul Goble	Science/Sound
The Boy Who Harnessed the Wind	William Kamkwamba and Bryan Mealer	Science/Energy
Roller Coaster	Marla Frazee	Science/Physics
Pigs Will Be Pigs	Amy Axelrod	Mathematics/Money
Inch Worm and Half	Elinor J. Pinczes	Mathematics/Measurement
Tar Beach	Faith Ringgold	Mathematics/Geometry
When Charlie McButton Lost Power	Suzanne Collins	Science/Electricity

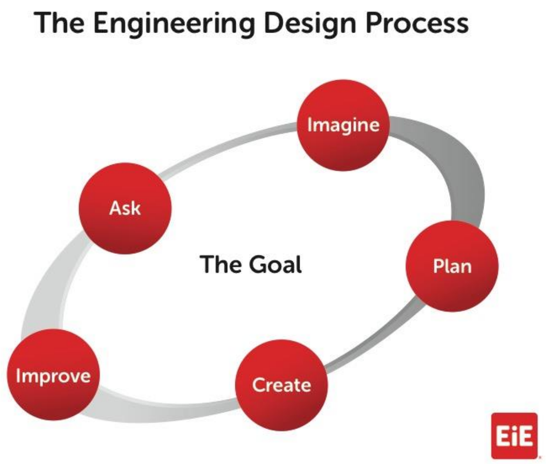
STEM Education in Elementary School

Many times, when teachers think of "STEM Education," they imagine robotic competitions or computer

labs. STEM is usually considered a high school initiative, or maybe a middle school program, and not for an elementary classroom. However, there are many reasons for the use of design challenges with elementary aged children, including the way they support literacy learning.
Through science and mathematics, we work to explain our world. Engineering drives advances and with the use of technology, we are able as people to revolutionize and improve every aspect of human life. Elementary school students can start to develop the habits of mind, curiosity, creativity, perseverance and resilience (Costa & Kallick, 2008) to meet the needs of their tomorrow's civilization.

A key element to STEM lessons is the Engineering Design Process (see figure 3).

Figure 3. The Engineering Design Process (Museum of Science, Boston, 2015)



The beauty of the engineering design process is twofold: First, it is really the process that working engineers use. Secondly, it does not start at any particular point, nor does it necessarily follow in lock step. For example, an engineer might start with a product that already exists, or one that needs improvement. So, it would start at the "improve" stage. Or, after "creating" a prototype, if it does not work like intended, the engineer steps back to the "plan" step, or she may go back through the "ask," "imagine," and "plan" steps to "create" a new prototype. The importance of this process for elementary students is that it means failure is not the end. Failure is a key element of the process of making progress. This is a very healthy understanding of what to do when something does not work, whether it is designing a water purification instrument, or if it is solving a math problem. The parallels to reading comprehension should seem obvious. As readers, when we don't understand a passage we just read, we go back and reread, maybe slower, or out-loud until we get it and can go on. Not giving up is a foundation of a Growth Mindset (Dweck, 2007) where students believe that with continued effort, they will be able to achieve.

The Lesson Plan

STEM lessons can be a one-lesson activity with a theme, up to a unit of lessons that build bigger concepts in science and/or mathematics. The format can be any combination of lessons between these extremes. The lesson in Figure 4 can be completed in one long session or broken into two sessions. It also can be appropriate for students ranging from first through third grade.

Figure 4: STEM Lesson Example

Goals:

- To apply attributes of triangles and squares to build a standing structure with marshmallows and toothpicks.
- To persevere in the face of difficulty.

Materials:

- 1 copy of the book, *Roberto, the Insect Architect,* by Nina Laden,
- 500-600 toothpicks,
- Yard stick or 2 rulers
- 1 bag of mini-marshmallows for part 1 (spread them out on newspaper, and let them sit out overnight to get a little stale- makes them easier to manage),
- for each pair of students:
  - 1 paper plate
  - a snack bag with 30 marshmallows for part 2 (again, use stale marshmallows),

Procedure:

1. Ask students what an architect is. Discuss how they plan buildings, using blue prints. Read the story, *Roberto, the Insect Architect,* to the students in a whole group. Stop at various points to check comprehension and/or highlight aspects that link with current reading lessons.
2. After the story, ask students what geometry is. (A study of shapes). Ask what shapes they know. Ask if students know what 2-D and 3-D mean ("flat" shapes versus "fat" shapes). Tell students their task will be to create 3-D figures out of triangles and squares. Demonstrate how to use the marshmallows to connect the toothpicks. Students will build pyramids and prisms.
3. Pair students up, and assign them to sit together. Give each partner team a plate, a handful of loose marshmallows (not the snack bag) and 10-15 toothpicks. Give students 8-10 minutes to build as many 3-D figures as they can.
4. Have students stop so you can lead a discussion. Choose a cube that a team has built. Put it under the document camera or in your hand so students can see it. It will probably start leaning to one side. Ask students, "What is happening?" Talk about the sturdiness of the figure. Choose a triangular prism, and ask students about the sturdiness of this figure. Continue with a square pyramid, and a triangular pyramid. Help students articulate a conjecture that is similar to: the more triangles in the figure, the sturdier it becomes. Write it on the board, or post it on a sheet of construction paper to be able to refer students back to it during their building time. (You can stop here if

you wish to do the lesson in two sessions)

5. Have students clean their tables, disassembling their structures, throwing marshmallows away, but keeping toothpicks and plates. Distribute the baggies of 30 marshmallows to each team, and more toothpicks if they need them.
6. Tell students that Roberto needs their help! Their challenge is to build the tallest building they can by using 30 marshmallows. Let students work with their partners. As you go around, ask questions such as:
    - What is your strategy?
    - (When towers are leaning) Where does the problem start?
    - How can you use the information in our conjecture to make it stronger?
    - Is there a way you can change your squares/rectangles into triangles?
7. After they have been working for 10-12 minutes decide if students could benefit from seeing other teams' structures. If all teams are making a successful building, then they do not need to do this. However, if some teams are struggling, and some teams are working successfully, do a Museum Walk in a modified version we nicknamed a "Walk-About." Have students stand up and clasp their hands behind their backs. Tell them to calmly walk "about" with their partners, to look at other people's towers. They are to look for ideas that will help them make their buildings better. They need to keep their hands behind their backs to remind them not to touch other people's work. When they have seen everyone's, they may return to their seats.
8. Lastly, give students about 10-15 more minutes to work. Call time. Gather students to do a formal Museum Walk. As a whole class, go to each building and have the builders explain what they did. Measure their height. When everyone's tower has been examined, congratulate students on sticking with the building, even when it was hard!

With a class of second graders who were within days of becoming third graders, a sign of success was children exclaiming, "I wish we could do it again!" during the final museum walk! Nevertheless, this lesson can serve as an example of the connection between strong literacy teaching strategies and a successful engineering design challenge.

The Use of Queries

In the quest to help children learn to understand text, Moats and Hennessy (2010) describe the use of "queries," a form of questioning distinct from traditional questions by the purpose. "They are designed to promote insight, questioning, clarification and inference-making- both gap-filling and bridging" (Kintsch, 2005). Designed to require longer, more thoughtful and more elaborate answers at critical points in the narrative, (Moats and Hennessy, 2010) queries are useful during STEM lessons to require deeper thinking, the application of prior knowledge, and to identify problems in plans that prohibit the goal from being achieved. (See Figure 5 for example queries for use for literature).

Figure 5. Queries to use with Literature
1. What was the reason for that? 2. Why do you think the character did that? 3. Is that part clear to you? 4. What problem is this character trying to solve? 5. What do we know about ______ at this point? 6. What do you wish would happen here? 7. Were you surprised here? Why or why not? 8. What might happen now? (Moats and Hennessy, 2010, p.78)

In this lesson, the goal of the design challenge was for students to use knowledge about sturdy structures to build a toothpick and marshmallow building that could stand on its own. In the first part of the lesson, where students built "simple" polyhedra (consisting of one prism or pyramid made exclusively with triangles and/or squares), they learn through the construction and the class discussion that figures with mostly triangles (like a triangular pyramid) are studier than ones with mostly squares (like a cube). Using this understanding in building a standing structure will help them to be successful. Unfortunately, most children in their first attempt at solving a design challenge do not apply the prior knowledge just discussed.

Queries, with their open-ended structure and their focus on reflection were helpful in guiding students to modify their plans to include more triangles. As students got started, the queries we used included:

- What shapes are you planning to use?
- What kind of strategies are you going to use to make it sturdy?
- What shape are you using for the base?

As students were facing leaning towers or buildings that would not stand at all, our queries were:

- Where is it not being sturdy? Is there something you can do to strengthen that part?
- Do you want to talk about your building?
- Can you see the problem?
- How could you make triangles where you have squares?

Moats and Hennessy state that when using queries in the course of comprehending narrative text, the focus should be on the "connections between *who* is doing *what* and *why* they are doing it." (p. 78). We contend that queries in the course of a design challenge should focus children on the connections between what they are doing in light of previous findings. In this example, what do the children use to make a building stand, in light of the common understanding of constructing sturdy structures with triangles and squares?

Finally, queries to focus reflection are quite possibly the most important aspect of the design challenge. In literacy lessons, this would be equivalent to the summarizing (Cecil & Gipe, 2009) of what a student read. Reflection of a design challenge could include articulating, either orally or in writing, what steps they took to accomplish the goal, what worked and what went wrong. Ideally, a reflection should also include next steps, or possible changes if they did it again. In this case, as we went around the room, Museum Walk style, we asked students to explain to the class what they did as we examined the buildings. Some prompting questions included:

- What did you do to make it stand up?
- Did you make any changes to your design after the walk about?
- Was this your first design? If not, what made you decide to start again?

Summary

STEM design challenges integrate foundational literacy skills at all stages of a project. Literacy teachers who make the connections between strong literacy teaching strategies and STEM lessons have the potential to build strong problem solvers, no matter the age, in reading, math, science and even engineering!

References

Bybee, R.W. (2013). The case for STEM education: Challenges and opportunities. Arlington, VA: NSTA Press.

Cecil, N.L. and Gipe, J.P. (2009). *Literacy in grades 4-8: Best Practices for a Comprehensive Program 2nd Edition.* Scottsdale, AZ: Holcomb Hathaway Publishers.

Costa, A. L. &Kallick, B. (ed.) *Learning and Leading with Habits of Mind.* Alexandria, VA: ASCD. URL: http://www.ascd.org/publications/books/108008/chapters/Describing-the-Habits-of-Mind.aspx

Dweck, C.S. (2007). *Mindset: The new psychology of success. How we can learn to fulfill our potential.* New York, NY: Random House Publishing Group.

Kintsch, E. (2005). Comprehension theory as a guide for the design of thoughtful questions. *Topics in Language Disorders, 25*(1), 51-64.

Laden, N. (2016). *Roberto, The Insect Architect.* San Francisco, CA: Chronicle Books, LLC.

Moats, L.C. and Hennessy, N. (2010). *LETRS Module 6: Digging for meaning: Teaching text comprehension*. Boston, MA: Sopris West.

National Academy of Engineering (2008). Grand challenges for engineering. Washington D.C.: National Academy of Sciences.

The Engineering Design Process Poster Image, Boston, MA: Museum of Science Retrieved from http://www.eie.org/eie-curriculum/resources/engineering-design-process-poster-image, on June 5, 2016.