INTERNATIONAL LITERACY ASSOCIATION

Connecting Compassion: Empathy's Role in STEM and Literacy Integration

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Children's literature offers an ideal context for students to develop belonging and nurture empathy as students create solutions for characters through engineering design.

Mr. Austin (all names are pseudonyms), an experienced second-grade teacher in a classroom characterized by students with varying reading abilities, is continually looking for ways to inspire his students, challenge them to think beyond the classroom, and develop a sense of belonging. One of his students, Suzanna, is a struggling reader, and her family does not seem to value Suzanna's time at school. Meanwhile, Daniel is a beginning English language learner, and he only speaks English while at school. On the other end of the spectrum, Ava, an advanced reader, already describes math and science as "yuck" and uses avoidance behaviors for any learning activity that is not specific to reading and writing. While Mr. Austin's primary focus is on his seven- and eight-year-old students, he also projects and carries a sense of responsibility and concern for their future when his students become 37- and 38-year-olds. Mr. Austin believes that modeling and teaching students to exhibit empathy inside and outside of school is a crucial cognitive tool for his students, and in his role as a teacher, but more importantly, Mr. Austin identifies empathy as a pivotal component to bolster current reading comprehension now and broaden his students' perspectives and the possibilities for their futures.

Integrating Empathy in STEM Education

The world is experiencing swift and profound transformations, propelled by rapid advancements in globalization and technology (Daugherty & Carter, 2018; National Academies of Science, Engineering, & Medicine, 2021). Throughout the past two decades, researchers, political and civil leadership, educators, and employers have been tasked with actively exploring essential practices to enhance and implement improvements in STEM education (Archer et al., 2020; Emrey-Arras, 2018; Hodson, 2003; National Research Council, 2012). Considering the impact of globalization and the transition towards an innovation-driven economy that prioritizes collaboration, communication, creativity, and critical thinking, it has become crucial for researchers, school leaders, and teachers to undertake the responsibility of instilling students with the mindset and essential skills required to prepare them for future jobs that may not have yet been conceived (Albro & Turner, 2019). In elementary schools where teachers are typically generalists, the possibilities for integrated STEM education learning experiences are unlimited. Integrated STEM education is a teaching methodology that breaks down subject-area boundaries, combining science, technology, engineering, and mathematics with other subjects. Through hands-on and team-based projects, students apply content knowledge from multiple STEM subject-areas, thereby practicing usage of the given content as well as fostering critical

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thinking and problem-solving skills. With the power to forge connections between different disciplines, instill practical, real-world applications, and challenge students to be critical thinkers and problem-solvers, integrated STEM education enriches students' learning experiences and prepares them for an interconnected world (Cook & Bush, 2018; Daugherty & Carter, 2018; Kelley & Knowles, 2016).

Improving the results of STEM content in schools remains a reoccurring theme in integrated STEM education. Utilizing real-world learning experiences and encouraging student creativity through problem solving are characteristically viewed as the best avenues for fostering students' attraction to and dedication to STEM (Franco & Patel, 2017; McBride et al., 2020; Oppermann et al., 2019). Nevertheless, despite the sustained investment of time and resources to STEM education, students' engagement in STEM within schools has remained persistently unchanged, and there has been a discernible decline in the number of American students who go on to pursue STEM disciplines in the workforce (Archer et al., 2020; Frady, 2021; National Science Foundation, 2018; Ro & Knight, 2016).

PAUSE AND PONDER

- In what ways can empathetic characters in narratives be used to introduce integrated STEM concepts effectively in your classroom?
- How might empathetic narratives serve as a catalyst, engaging students in integrated STEM concepts that would otherwise fail to create a sense of competence and belonging?
- How can story grammar ignite students' passion, inspiring them to tackle problems using the engineering design process?

Researchers argue that social and emotional skills, such as empathy, are critical but often neglected in STEM education (Walther et al., 2017, 2020). Empathy is the abstract concept of striving to mentally recognize and fully perceive and understand another individuals' needs and wants (Cuff et al., 2016). According to Sun (2017), "engaging students in empathy can make STEM learning more meaningful because students can see the impact of STEM in their lives and the lives of others" (p. 6). Enriching integrated STEM education by prioritizing empathy as a critical element holds the potential to connect a wide-ranging assortment of learners to STEM, while also strengthening the content knowledge and skills students need to undertake in a complex and changing world. Additionally, if student persistence in STEM is to be a primary objective of STEM education, teachers should utilize every tool available to focus on initiating early and sustained interest at a young age (McClure et al., 2017). By encouraging empathetic solutions through authentic, hands-on, experiential learning, teachers may play a pivotal role in shaping students' attitudes towards viewing STEM disciplines as "working with people" as opposed to "working with things" fostering not only initial interest but also the resilience needed to overcome challenges ahead in their educational journey (Capobianco & Yu, 2014).

Unfortunately, teachers who hold expectations centered around deficits have a restricted view of their responsibility in educating their students (Lazar et al., 2012). For example, some teachers may attribute the underrepresentation of women in STEM fields to perceived deficiencies or limitations in the abilities or interests of female students rather than considering broader factors such as systemic biases, societal expectations, or lack of encouragement. This deficit mindset may hinder efforts to address gender disparities in STEM fields by not recognizing and addressing the external barriers that contribute to the underrepresentation of certain groups (Capobianco & Yu, 2014; Edwards et al., 2019; Frady, 2021). Considering the persistent underrepresentation of women in engineering, science, technology, and mathematics careers (U.S. Bureau of Labor Statistics, 2022; NSF, 2018; O'Brien et al., 2023), Capobianco and Yu (2014) propose reframing the STEM fields as 'caring professions' by instilling empathy in elementary-level problem-solving processes. Edelen et al. (2019) contend that the long-awaited inclusion of underrepresented talent in STEM ultimately depends on championing empathy to students as an integral element of both problem solving and inclusivity within STEM fields:

> When students are solving a problem for someone else, they are positioned as the one in charge of their own learning who has valuable insights and contributions to help another. Students develop an immense compassion for the person(s), organism(s), or environment(s) for which they are solving the problem and begin to seek out the knowledge they need to solve the problem on their own (p. 11).

An example of this might entail older students authentically enhancing their own reading and communication skills through fostering a sense of empathy and mentorship towards younger students who would benefit from a reading partnership. By rethinking a traditional 'reading friends' program and modeling a caring school community, the older students could plan, design, and construct upcycled book totes from recyclable materials and then team up with the younger students to provide one-on-one reading support.

Emphasizing Empathy and Contextual Learning

Gee (2015) expands on the significance of human-centeredness and its intrinsic link to literacy, underscoring that "learning involves an active engagement with the world, with words and with other people" (p.88). This sociocultural approach to literacy and language learning shifts the focus from the individual to others, offering young readers an authentic means of thinking rather than adhering solely to a skill-based approach to reading (Alvermann et al., 2019; Hall, 2010; Hassett, 2008). Moreover, Vygotsky (1978) emphasizes the practical application of education, explaining that teaching should integrate reading and writing in contexts directly relevant to students' lives. Books have the potential to inspire empathy, curiosity, confront challenges, and celebrate diversity, particularly when educators encourage discussions about reading; in contrast to classrooms that often focus on high-pressure reading performance and response (Forsythe et al., 2019; Heath, 2013).

Traditionally, informational texts, expository material that is designed to convey content knowledge about the natural or social world in a straightforward and objective manner (Hackett-Hill, 2021), have been associated with integrated STEM education as the tool to communicate knowledge, while narratives serve a different but equally important purpose to teach readers about the social world and provide insights into navigating complex emotions and conflicts (McTigue et al., 2015). Reconceptualizing narratives as an ideal conduit for elementary integrated STEM education has the potential to transport readers into the lives and experiences of characters from diverse backgrounds, encouraging empathy and fostering a better understanding of different perspectives, cultures, and societal challenges. Moreover, picture books not only depict conflicts among characters originating from misunderstandings and misjudgments but also concurrently showcase characters undergoing growth and nurturing empathy for their fellow characters (Nikolajeva, 2013). Supporting this line of thinking, Cook and Bush (2018) acknowledge the power of combining empathy with engineering, science, technology, and mathematics through the problem-solving process, describing empathy as, "instrumental in 'lighting a fire' and getting students to be motivated, invested, and passionate about creating a solution to the problem" (p. 101).

Story Grammar and Engineering Design

By infusing instruction with engineering design (see Figure 1), a systematic and creative problem-solving approach, students' understanding and active engagement with literacy and language learning may be significantly enhanced (Daugherty & Carter, 2018; Wilson-Lopez & Gregory, 2015). This instructional infusion is often introduced through story grammar, the fundamental elements of a narrative encompassing the structure and meaning of a story, including characters, setting, and plot (Cheek, 2021; Sadow, 1982). Additionally, the term design thinking is commonly associated with the utilization of the engineering design process. Design thinking encourages students to wrestle with issues that require them to reimagine and redefine as they create a solution to a given problem (Cook & Bush, 2018). For instance, students could explore the traits of a character from a recently read story. Drawing on their understanding of the character's attributes, the

Figure 1
The Engineering Design Process

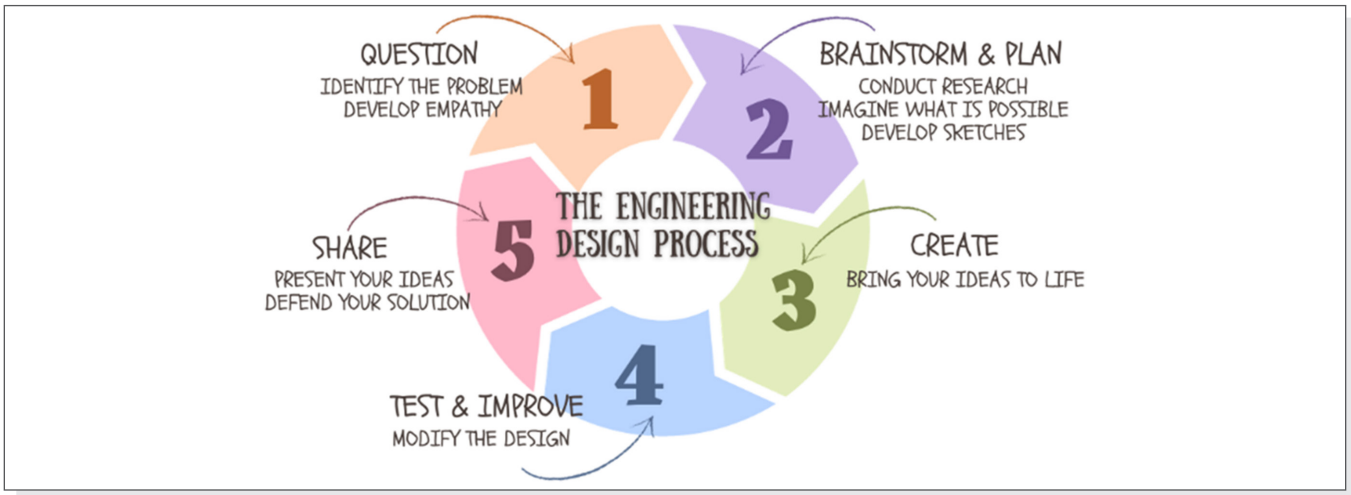


Table 1
Story Grammar and Empathetic Connections in Engineering Design

Book/author	Setting	Main character(s)	Plot/problem	Empathetic connection	Engineering design challenge
The Water Princess by Susan Verde	A rural African village where Princess Gie Gie and her family live. The village is surrounded by a vast, dry landscape with few sources of water	Princess Gie Gie: A young girl a young girl who lives in the village and dreams of having clean and easily accessible water for her family. She's determined and caring, always thinking of her family's needs	In the village, obtaining clean, easily accessible water is a challenge. The villagers, including Gie Gie and her mother, must walk a long way to a well and wait in line just to get a little water. They carry heavy containers on their heads, and the water is dirty and often runs out	Daily Struggles for Water: bright sun, thirst. frustration, longing, determination	Design a solution to help Princess Gie Gie and her friends create an efficient way to transport more water back to the village each day
Amazing Grace by Mary Hoffman	Grace's school and home in a diverse urban neighborhood	Grace: An African American girl with a vivid imagination and a passion for acting	Grace wants to play Peter Pan in the school play, but other kids tell her she can't be Peter Pan because she is a girl	Insecurity and doubts about herself and her dreams; hurtful stereotypes; disappointment	Help Grace and her friends design and build a small, inclusive stage where everyone can participate and feel comfortable. Your stage should be adaptable and accessible to all students, just like Grace's dream of being Peter Pan
Joseph Had a Little Overcoat, by Simms Taback	A small village where Joseph lives	Joseph: An elderly man who owns a cherished overcoat	Joseph's overcoat has become old and tattered. He needs to find a way to reuse it rather than discard it	Worry, longing, sentimental attachment	Design and build practical and thoughtful gifts crafted from repurposed old clothing that can be presented as birthday presents to the residents of the nearby assisted living facility
The Snowy Day by Ezra Jack Keats	An urban neighborhood covered in snow	Peter: A young African American boy who is filled with curiosity and adventure as he navigates a snowy landscape	Peter wants to play in the snow but must overcome the challenges of deep snow and cold weather	Excitement, wonder, joy, cold, tired	Develop and create winter equipment that makes outdoor play more comfortable for Peter

(continued)

Table 1
Story Grammar and Empathetic Connections in Engineering Design (*continued*)

Book/author	Setting	Main character(s)	Plot/problem	Empathetic connection	Engineering design challenge
The Bear and the Piano by David Litchfield	A lush forest, where Bear discovers a piano hidden in the trees	Bear: A curious and talented bear who discovers the piano and becomes a skilled musician	Bear becomes an expert piano player and experiences fame and success in the human world but also faces the challenges of being separated from his forest home and friends	Excitement over learning something new, desire for friendship, difficulty in making choices	Design and make a musical instrument using natural materials found in the environment to enhance the peaceful outdoor setting without causing harm to nature
Interrupting Chicken by David Ezra	Little Chicken's cozy bedroom, where her father reads bedtime stories	Little Chicken: An enthusiastic and talkative young bird Papa Chicken: Little Chicken's father, who tries to read bedtime stories to her	As Little Chicken's father reads, Little Chicken repeatedly interrupts	Enthusiastic, impatient, frustration with interruptions	Design and build a device for Little Chicken based on an illustration in the book that uses electrical circuits to light up to signal when she wants to talk

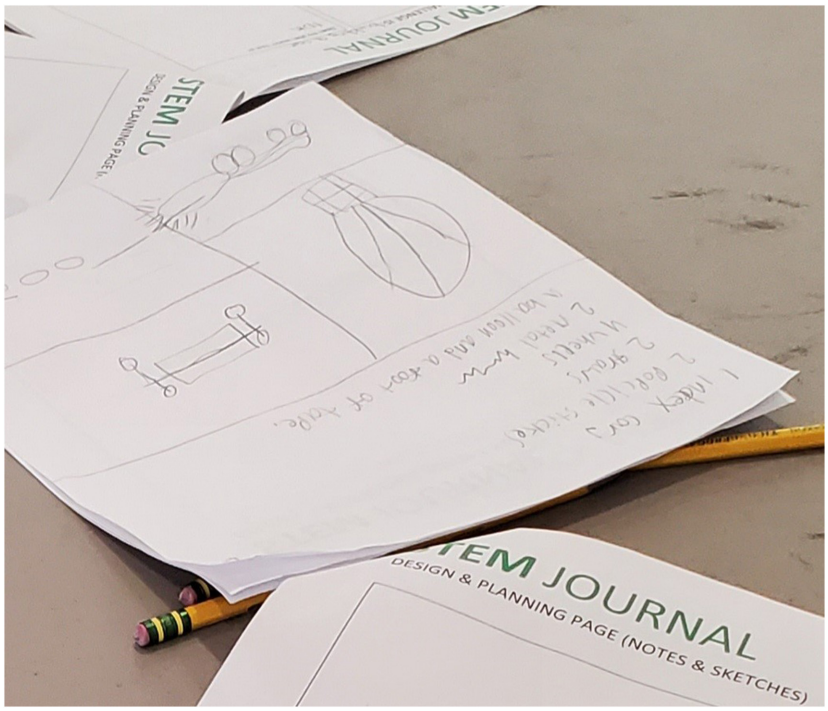
students could then engage in an engineering design challenge related to that character, designing a solution for a problem the character encounters in the story. As students integrate their knowledge of the character with their own experiences and perspectives, they develop a deeper understanding of both the fictional world and their own lives. This integration helps students make empathetic connections between the story grammar and their own experiences, fostering authentic and meaningful learning (Brewer & Phillippe, 2022; Bronfenbrenner, 1979).

Enriching Classroom Practices through Integration

Parsons and Ward (2011) advocate for the enhancement of classroom book talks by implementing authentic problem-solving tasks, enriching students' comprehension of content literacy through relevant work. Perspective-taking allows the reader or listener to contemplate how the narrator or characters articulate a story. Additionally, point of view prepares the reader or listener to acknowledge the distinctive voice and emotions of the storyteller. These tools not only deepen comprehension of the narrative, but also equip readers or listeners to grasp and empathize with the characters' emotions, motives, and experiences, thereby strengthening the connection to the narrative and forging a stronger sense of relatability (Brewer & Phillippe, 2022; Carpenter de Cortina, 2021; Hodges et al., 2018). Elementary teachers that seamlessly integrate perspective taking and point of view through story grammar in book talks, use the story elements as a framework for fostering empathy and introducing engineering design challenges and STEM content within their literacy program (Cheek, 2021; Sadow, 1982). This gateway, offering an early and compassionate introduction to integrated STEM for elementary students, particularly girls, may serve as a catalyst for an informed perspective of belonging in science, technology, engineering, and mathematics as well as an openness to future opportunities in STEM (Capobianco & Yu, 2014). This issue may also be compounded by the fact that many teachers and administrators associate the term STEM with meaning solely science content and missing the potential of integration and the abounding opportunity of connecting science with technology, engineering, and mathematics (Daugherty, 2009).

Intentional strategic teaching that equips students with goal-directed reading strategies, exploring both the structural elements of story grammar and the inner worlds and emotions of characters, is critical (Afflerbach et al., 2008). Characters are central to understanding the focus of the narrative as authors frequently utilize the characters' dialogue and actions as the catalyst to propel the storyline

FIGURE 2
Members of Team 4 Ideate in their Design Journal



Note: Guided by story grammar, the students have identified Gie Gie's problem and are using their engineering design journal to brainstorm and plan solutions to help Gie Gie efficiently transport water back to the village.

forward (Cheek, 2021). The fundamental emotions of the characters serve as a pathway for students to navigate the complexities of the characters' motivations and inner struggles. By exploring what drives the characters, students are provided with a pathway that leads them into the deeper layers of the narrative. This connection goes beyond the surface-level events and actions, allowing students to connect with the characters on a more profound level, fostering empathy as they gain insight into varying life experiences and perspectives within the narrative (Brewer & Phillippe, 2022; Wyile, 1999).

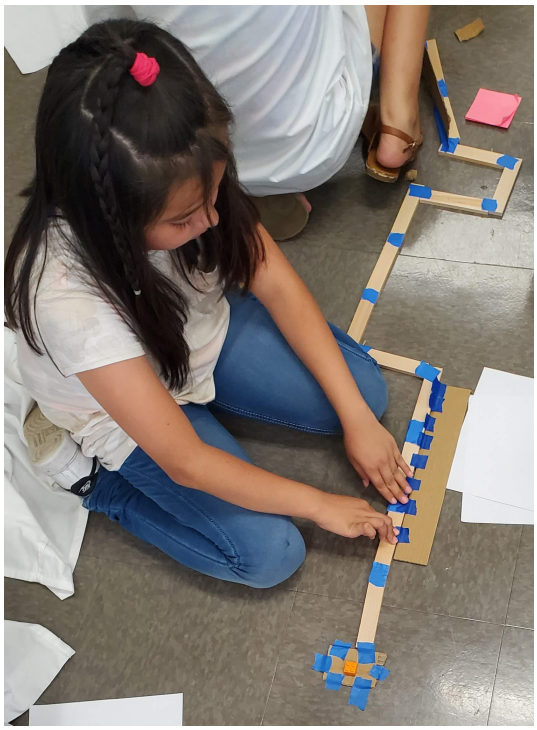
Stepping Back into Mr. Austin's Classroom

As teachers are often driven by a strong desire to continually improve their practice and make a meaningful impact on the lives of their students (Toll, 2017), Mr. Austin often begins planning with the standards and a picture book from the classroom library. To evoke the book's connection to empathy, Mr. Austin focuses on the story grammar, particularly the setting, the main character(s), and the plot/struggle in the story. For example, in the book *The Water Princes* by Susan Verde, the story is set in a small village in Africa, where it is very hot and dry. The village is surrounded by a vast, dusty landscape with few trees or sources of water. Gie Gie, the main character, is a young girl, devoted to caring for her family, who dreams about having clean and easily accessible water. The main plot/problem in the story is the scarcity of clean water in the village. Obtaining clean, easily accessible water is a challenge, and the villagers, including Gie Gie and her mother, must walk a long distance to a well and wait in line just to get a little water.

After identifying the story grammar, Mr. Austin links the natural empathetic connections evoked through the story grammar. For example, Mr. Austin believes his students will empathize with Gie Gie's daily struggles for water. The students may develop compassion for her thirst, frustration with the journey, and longing for water. Additionally, the students may identify with her resolve to improve the lives of her family and community.

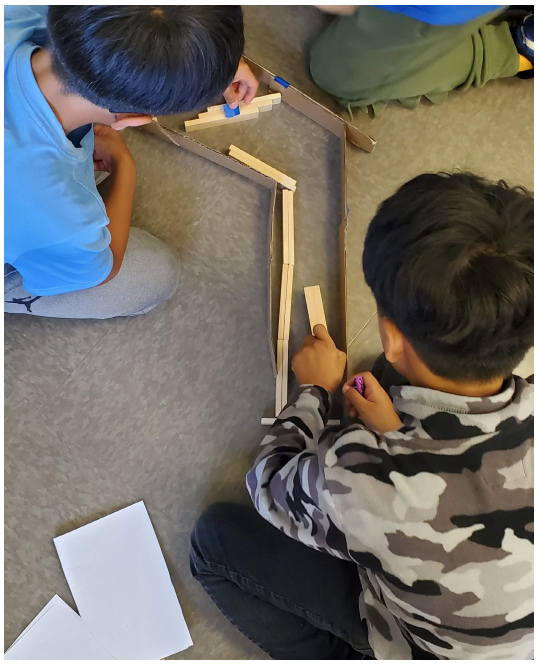
Guided by his passion to both strengthen his students' current reading abilities now and increase their perspectives and possibilities for their futures, Mr. Austin contemplates an authentic way to propel the story grammar and uncovered empathetic connections into a hands-on STEM

FIGURE 3
Members of Team 2 Create a Solution to Bring their Idea to Life



Note: Understanding the setting of the story and following their initial ideas, the team starts to build their water transportation system by constructing their solution with simple tools and materials.

FIGURE 4
Members of Team 1 Put the Finishing Touches on their Design



Note: Using a marble to simulate the flow of water, this team is implementing their design thinking skills to redefine their initial ideas and consider alternatives to improve their design.

design challenge using the engineering design process. Integrating the engineering design process into literacy offers Mr. Austin a flexible, non-linear approach that may empower his students with practical tools for deductive reasoning, enabling them to create and enhance various solutions while meeting the needs of others. By merging the story grammar and empathetic connections from *The Water Princess* into an engineering design challenge, Mr. Austin's student will have a hands-on problem-solving opportunity not only as a vehicle to integrate science, technology, engineering, and mathematics with literacy, but to contemplate how to improve the lives of others by reframing the STEM fields as caring professions.

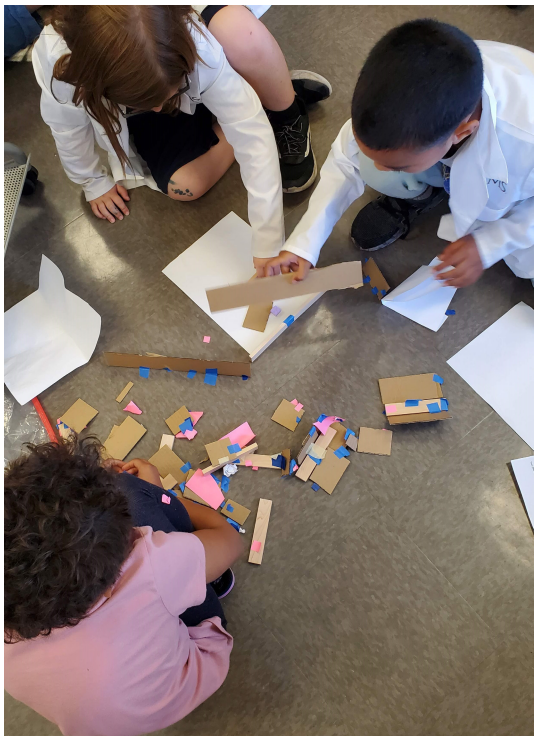
Integrating STEM education and literacy by intentionally infusing the engineering design process provides an authentic approach for students to apply and practice reading comprehension and writing strategies (Galaviz & Peralta, 2019; Isidro, 2021; Wilson-Lopez & Gregory, 2015). Students begin by identifying the problem that needs solving, empathizing with the end user, and then proceed to developing and building solutions. Students continuously test and modify, revisiting any stage as needed, before ultimately sharing the final solution (see Figure 1).

Empathy in Action

Early on a Tuesday morning, Mr. Austin eagerly launches the integrated STEM challenge inspired by *The Water Princess* during his literacy block. After a book walk followed by a read-aloud, Mr. Austin leads the class discussion by guiding his students to identify the story grammar. Once the class has identified the setting, main characters, and the problem, Mr. Austin prompts, "Imagine the daily journey Gie Gie must take to get water. How must Gie Gie feel, walking a long way every day just to get a drink? Think about how heavy the containers are on her head. Let's put ourselves in Gie Gie's situation and empathize, which means understand the feelings Gie Gie might have. What do you think Gie Gie is feeling?"

Hands quickly raise, but Mr. Austin informs the class they can just "popcorn" out their ideas. "Tired." "So thirsty." "Sad." "She doesn't like it." "She wants to help her family." Mr. Austin quickly jots down the responses on the classroom interactive white board. He proceeds to ask the

FIGURE 5
Members of Team 3 Redesign and Make Improvements after Testing



Note: Realizing that their first idea did not work, this team is authentically practicing engineering design by considering what parts of their original ideas were successful and what parts could be improved to transport water back more effectively to the village.

FIGURE 6
Members of Team 4 Test their Final Solution

Note. The team is conducting their final testing before presenting to the class. The team is using a marble to simulate the flow of water in their transportation system and considering how their design helps the village, culminating in an authentic learning experience.

students to nod if they have ever experienced any of these same feelings as Gie Gie. Heads bob.

Mr. Austin is amazed at what he calls the "superpower of empathy." Empathy not only enables students to form a deeper connection with the story but also serves as a bridge for students to recognize STEM as an integral part of compassionate professions that actively contribute to the welfare of others. He gestures to the anchor chart of the engineering design process that hangs in the classroom and says, "Princess Gie Gie wants to make life in her village better by finding a way to bring more clean water to everyone. Imagine you are an engineer, and it is your job to help Princess Gie Gie and her friends create a solution to efficiently transport more water back to the village each day. In today's challenge, you will design a way to transport water that works-well and is safe for kids to use."

Following this quick introduction to the engineering design challenge, Mr. Austin pauses to equip his "young engineers" with essential content knowledge, ensuring they are well-prepared for problem solving. In this case, Mr. Austin holds up *The Water Princess* and introduces the concept of "water scarcity." He integrates geography by contrasting online maps of regions with limited access to water with those depicting areas with abundant water resources. Next, Mr. Austin includes background information about how ancient societies, such as the Romans, used aqueducts to transport water to cities, emphasizing how the aqueducts were designed to move water using gravity. Finally, Mr. Austin showcases examples of innovative solutions that individuals or communities have implemented to address water scarcity, such as bucket and pulley systems, novel wheeled carts, and reuseable containers and cisterns.

Returning to the engineering design challenge, Mr. Austin shares a design brief with the class which will guide the integrated STEM lesson. Design briefs often include the content standards that will be covered, a specific and engaging scenario for the challenge, and tools, materials, and resources that will be available. The parameters or limitations of the challenge will steer the solutions. The students will be guided by the engineering design process evident by the completion of a written design journal that documents the students' thinking during the process. Finally, Mr. Austin will explain the assessment and evaluation process for the challenge, which often involves the use of a rubric. This is just one example of an authentic learning experience but the possibilities of integrating

story grammar, empathetic connections, and engineering design are only limited by the books available in the classroom (See Table 1 and Figures 2–6).

Conclusion

Researchers advocate for a more human-centered approach to STEM education that places others' needs at the nucleus of problem solving (Hynes & Swenson, 2013). Accordingly, scientists, engineers, and mathematicians must go beyond technical proficiency; they must also nurture social and emotional skills such as empathy, often underemphasized in STEM education (Walther et al., 2017, 2020). Fisher et al. (2023) stress the importance of classrooms that are rich with positive human connections where students flourish because the students feel a sense of control and understand the content, they are learning is important. By infusing empathy into the classroom through story grammar as well as incorporating character experiences into engineering design challenges, students are encouraged to consider the scale of a problem and its impact on individuals and the broader community. This empathetic approach transforms students' outlook from merely completing assignments to assuming responsibility for solving real-world problems affecting others (Cook & Bush, 2018). Given the missing talent in STEM, the integration of literacy and STEM through the lens of empathy possesses the ability to not only enhance current reading comprehension now, but also ignite the possibility of fostering a sense of belonging within the fields of science, technology, engineering, and mathematics later.

TAKE ACTION

1. Begin with your standards and a picture book from your classroom library.
2. To draw out empathetic connections, focus on the story grammar, particularly the setting, characters, and plot.
3. Consider the problem that the character(s) are facing in the story that could be solved using the engineering design process.
4. Link the natural empathetic connections evoked through the story grammar with the authentic compassion of your students.
5. Propel the story grammar and uncover empathetic connections as students develop a solution to an engineering design challenge (see Figure 1).

Conflict of Interest

We have no known conflict of interest to disclose.

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