Journal of Literacy and Technology
Volume 24, Number 1: Spring 2023
ISSN: 1535-0975


# Introducing Young Learners to Robots and Coding through the Very Hungry Caterpillar

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ISSN: 1535-0975

## Abstract

Educational robots are a technology tool that can be used in classrooms with young learners to enhance students' interest, engagement, and achievement in STEM subjects. By including the reading and writing "R" and the arts "A" in STEM, teachers can develop STREAM lessons that foster foundational literacy skills through creative and playful learning experiences. This article shares research-based best practices for integrating STREAM into the instruction of young learners. A first-grade lesson that connects robots and coding with Eric Carle's (1969) children's book *The Very Hungry Caterpillar* while incorporating concepts from science, mathematics and the arts is presented. Strategies for extending and adapting the lesson through writing, journaling, and additional pieces of children's literature are also discussed.

**Keywords:** educational robots, interdisciplinary learning, art, reading, writing

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Employment in science, technology, engineering, and mathematics (STEM) occupations has grown 79% in the United States since the 1990s and is expected to grow by another 13% by 2027 (Funk & Parket, 2018). However, according to the National Science Foundation Human Resources Advisory Committee (2020), many Americans enter the workforce without a basic understanding of STEM facts and approaches. STEM education has become a priority of schooling systems worldwide seeking to implement STEM content into the curriculum (Pressick-Kilborn et al., 2021). For example, Greece began requiring coding education starting in 3rd grade, France in 5th grade, and Spain, Germany, and other countries have indicated that computing will become a compulsory part of the curriculum (Rich, et al., 2018). In the United States, the Computer Science for All initiative was launched in 2016 to help all K12 students to learn computer science skills so they may be equipped to participate in a digital economy and a technologically-driven world (CSforALL, 2022).

With the inclusion of arts into the STEM approach, STEAM education has emerged as a method that recognizes student creativity as an essential component of the scientific literacy of the younger generations (Aguilera, & Ortiz-Revilla, 2021). The approach has also been extended to STREAM, with a focus on connecting reading, writing, and arts with the four STEM disciplines (Subramaniam et al., 2022). Using the STREAM approach, teachers can develop lessons that teach students these foundational new literacy skills through creative and playful learning while reading children's literature and linking the story to content across the STEM subject areas. By adding reading and multimodal literacy, students can express learning outcomes of STEM content through creative writing, journaling, and poetry while capturing what is learned in their own voices.

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Educational robots are a technology tool that can be used in and out of school environments to enhance students' interest, engagement, and academic achievement in STEM subjects (Anwar et al., 2019). Such robots can take on multiple forms, from student robotics kits to fully programmed socially assistive robots used in the classroom to aid student learning (Papadopoulos et al., 2020). Coding is a set of instructions a robot can read and execute, and the skill of creating code is increasingly recognized as a new literacy that should be fostered at a young age (Monteiro et al., 2021). As creative approaches to STEM, STEAM, and STREAM continue to gain importance, educators need to know how to implement such interdisciplinary lessons into the classroom starting at the earliest grade levels. This article shares research-based best practices for integrating STREAM into the early elementary grades. A first-grade lesson that connects robots and coding with Eric Carle's (1969) children's book *The Very Hungry Caterpillar* while incorporating concepts from science, mathematics and the arts is presented. Strategies for extending and adapting the lesson through writing, journaling, and additional pieces of children's literature are also discussed.

## Background and Literature

### *Evolution of STEM and STEAM Education*

As education reform efforts continue to call for connecting learning in subject areas and ending the fragmentation of disciplinary knowledge, educators have planned and implemented integrated lessons focusing on STEM and STEAM. Some issues or themes that surround the literature include interdisciplinary teaching and learning through connections in disciplinary knowledge; innovative and ambitious instructional practice; and real-world problem solving

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through active engagement of students in a variety of learning experiences (Holmund, Lessig & Slavit, 2018). Starting with STEM education a possible definition can be considered:

> STEM education is an interdisciplinary approach to learning where rigorous academic concepts are coupled with real-world lessons as students apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise enabling the development of STEM literacy and with it the ability to compete in the new economy (Nathan & Nilson, 2009, p. 3).

For STEAM education efforts, a possible definition can be considered: STEAM Education is an approach to learning that uses Science, Technology, Engineering, the Arts and Mathematics as access points for guiding student inquiry, dialogue, and critical thinking (The Institute for Arts Integration and STEAM, 2022).

> STEAM is a way to take the benefits of STEM and complete the package by integrating these principles in and through the arts. STEAM takes STEM to the next level: it allows students to connect their learning in these critical areas together with arts practices, elements, design principles, and standards to provide the whole pallet of learning at their disposal. STEAM removes limitations and replaces them with wonder, critique, inquiry, and innovation" (The Institute for Arts Integration and STEAM, 2022).

The content of the arts includes a variety of social, cultural, contemporary and historical concepts. In education, the arts are often taught by focusing on the performance or production of artistic understanding (art production and performance), the historical and contemporary influences of culture (arts history), the philosophical contemplation of why and how artworks or performances can be defined (aesthetics), and the analysis, interpretation and evaluation of

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artworks or performances (arts criticism). It is the combination of these four study areas that form the foundation of art education. For students studying the arts helps to connect concepts in a variety of disciplines and make sense of the world and themselves (Goldberg, 2016). As a form of communication and meaningful expression, the arts are valued in society for many reasons including an avenue for developing students' creative potential, for promoting critical thinking and reflection, and for innovating the future (Szekely & Bucknam, 2012). The disciplines of art history, art criticism, art production/performance and aesthetics are closely connected and are an integral part of all learning when the arts are integrated into STEM becoming the STEAM approach to curriculum (The Congressional STEAM Caucus, 2013).

The arts are best taught in a safe learning environment where students feel secure to express their ideas freely. Since creating artistic work is a reflection of students' lives, students' interests and exploration of concepts should be valued and integrated into arts learning. Through arts integration, students learn to create expressive work, consider philosophical ideas about the arts, discuss artistic work, and study historical and contemporary connections to culture. The goal of learning in and through the arts is to better understand the self, others, community, and the world (Anderson & Milbrandt, 2005). Using the STEAM approach requires educators to value all of the integrated disciplines. Curriculum that reflects the STEAM model has the potential to actively engage students in meaningful learning that impacts their lives and others with whom they interact. With the inclusion of the arts into the educational STEM approach, STEAM emerges as a method that recognizes student creativity and as an essential component of the scientific literacy of younger generations (Aguilera & Ortiz-Revilla, 2021).

### ***Research on Robots and Coding and Young Learners***

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There has been a steady growth in the number of studies examining educational robotics and their impact on young learners' social and academic skills (Anwar et al., 2019). Regarding young learners, Toh et al. (2016) systemically reviewed 27 studies that focused on the use of robots in early childhood education and found the ways robots in education aid in children's behavior and development revolved around four themes:

- Problem-solving abilities, team skills, and collaboration
- Achievement scores, science concepts, and sequencing skills
- Language skills development
- Participation

These findings highlight how using robots in education has the potential to influence young learners in the areas of cognitive, language, and social development. For example, in one of the studies reviewed Varney, et al. (2021) examined an in-school program that introduced LEGO robotics to foster young learners' interest in STEM topics. The program was adapted from a successful summer program but offered with no financial burden to third-grade classes at a Lansing, Michigan, United States elementary school with a diverse population during regular school hours. The program's effectiveness was shown through teacher testimonials, with teachers reporting students who had participated exhibited character development traits like teamwork skills, were more focused and engaged in STEM discussions, and showed a deeper understanding of certain math and science concepts. Another study that Barker and Ansorge conducted (2007) was aimed at assessing impacts on student achievement and examined an after-school science and technology program based on robotics for 9- to 11-year-olds in a Nebraska, United States, elementary school. Through the program, students used a LEGO robotics kit to

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build a "tankbot" and then ROBOLAB software to program their creations to do increasingly more complex tasks. Experts from the Carnegie Mellon University Robotics Academy developed the curriculum for 4-H, and the assessments used were based on the 4-H curriculum. The study results demonstrated that youth who participated in the program had significantly higher posttest scores, and the control group had no change in mean scores from the pretest to the posttest. Regarding robotics and language development, a robot storytelling system called GENTORO was studied by Sugimoto (2011) at an elementary school in Japan. Children can use the system to express their stories by making the robot play them in an immersive environment that integrates virtual and physical features. The results of the study indicated that the robot system enhanced children's participation and engagement in tasks and supported their design and expression in creating digital stories.

These are some of the studies focusing on how young students are using robots to enhance learning. This shows a need for pre-service teachers to be prepared to implement robots into their future classrooms. Xefteris (2021) created a course for undergraduate pre-service teachers focusing on creating a multidisciplinary curriculum with robots named "S.T.E.A.M Teaching Scenarios using Educational Robotics". Students in this course explored storytelling techniques, created stories, exploring music, history and art using a variety of different robots. More programs such as this one could make pre-service teachers more confident incorporating robots in classrooms of young students.

### *STREAM: Putting the "R" in STEAM*

The importance of expanding the STEM and STEAM approach to include reading/writing thus becoming STREAM is supported by the benefits students gain. Storytelling

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is an effective strategy for integrating STREAM into education (Martinez & Nolte-Yupari, 2015). Expressing knowledge through different media supports students' literacy development and can be implemented through an interdisciplinary approach, STREAM.

Journaling, sometimes called freewriting, gives students the opportunity to write for themselves and capture their initial impressions about a topic. Barbieri (1995) tells her students about freewriting and explains, "words came onto the page that I had not intended; the whole point of what I had been trying to say became clear to me, and I knew what I needed to write next. Stunned, I thought I had discovered magic" (p. 16). Freewriting also encourages students to share their unique writing voices. Romano (2004) believes, "crafting voice is necessary in order to write, and for me at least, to make it more interesting" (p. 11). Students can use freewriting to write about their classroom experiences with technology and working with robots.

Teachers need to provide their students with time to discover and share their ideas. Fletcher (1993) elaborates, "helping young writers find this inner voice starts with time – giving young writers the regular time they need" (p. 72). In addition to using freewriting as a method of expressing their reactions and opinions, students may choose to write fictional stories, perhaps a sequel to the story discussed in class, or draw pictures. Rief (1992) argues, "creating is the highest form of intellectual development" (p. 149). If students write an original story, they may choose to return to the robots to act it out. Graves (1994) advises teachers, "for some writers a new topic may emerge while they are writing about another" (p. 82). Therefore, writing about an experience with the robots in the classroom may lead to an idea for a short story or a poem. Heard (1999) values connecting writing with art to develop new ideas and teaches students, "and as you draw, write your thoughts down alongside your drawing. I usually draw a little, then

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write, then draw again, then write" (p. 101). Journaling provides opportunities for students to explore thoughts and use freewriting as a starting place to implement innovative ideas.

### *STREAM Benefits for Young Children*

The National Association for the Education of Young Children (NAEYC), the largest early childhood professional association in the United States, defines the early childhood years as being from birth through eight years and considers early childhood education an indispensable aspect in shaping dispositions, skills, and love for learning that will last a lifetime (Copple, & Bredekamp (2009). The early years are an important developmental time frame to help children develop positive connections with integrated learning approaches like STEAM. The positive learning experiences must be frequent and itself sustained with guidance commensurate with the learning needs of the child - altogether these factors lead to a greater likelihood of long-lasting benefits for children and affect their learning potential (NAEYC, 2009).

According to a cognitive development theory proposed by Piaget (1957, 1969), young children are biologically-driven to explore their environments using sensory experiences (e.g., motor, sight, sound, taste) and in developing language through reflection. As a result, children's memory systems are constructed (schema building), facilitated by gaining knowledge and direct experience. Vygotsky's cognitive theory (1986), which proposed that thoughts and language are intricately intertwined, further emphasized the importance of adult role models or other children that have more experience to act as guides. Therefore, during the early years introducing concrete and hands-on learning activities can help the child make the connection between STREAM ideas and language or thought.

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Encouraging a playful learning environment nurtures creative play and positively affects children's cognitive, physical and socio-emotional development. "Play awakens the creative energy needed for intellectual development and for healthy human development as a whole" (Nell & Drew, 2013, p. 29). Connections through STREAM create deeper comprehension and appreciation of not only the aesthetic qualities of the work but can also lead to valuing creative playful learning (Nell & Drew, 2013).

**Description of the Lesson**

As Monteiro et al. (2021) point out, "bringing computing into the education of young children is necessarily an effort that cuts across disciplines. Separating computing from other school subjects neglects its social and cultural branches and falls short of the goal of encouraging active and critical engagement with technology" (p. 5). The interdisciplinary STEAM approach can be used to introduce young learners to robotics and coding through lessons that integrate material across subject areas. The lesson described in this article is an example of how the use of robots and coding can be integrated with science, reading, art, and mathematics for students in the lower elementary grades. The robot used for this project was provided through a grant awarded to a Florida U.S. university faculty member to support community-engaged research with local organizations. Faculty members from the university visited the K8 school in early 2020 and observed the lesson.

***The Educational Robot Used***

The Dash & Dot robots are educational robots created by Wonder Workshop (Huang et al., 2019). The robots have built-in sensors such as a speed sensor and an infrared sensor, as well as sound and light effects allowing for interaction between the robot and the child (Huang et al., 2019). Dash is a small mobile robot, and Dot is a smaller sidekick. Children can use block coding to program the robots with an iPad app using these robots. A diagram of the Dash robot used in this lesson is shown in Figure 1.

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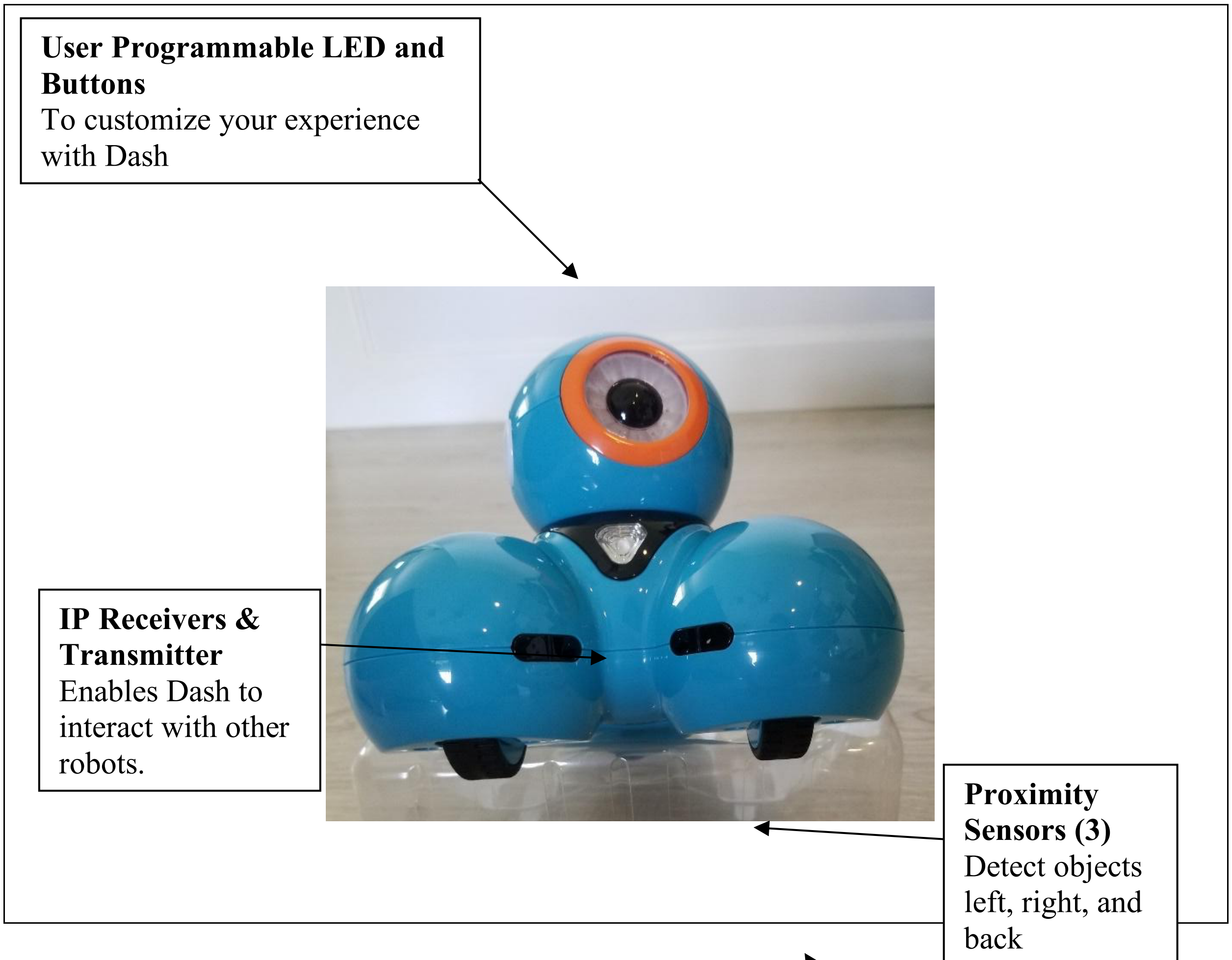
Figure 1. Dash the Robot




*Note:* Adapted from https://www.makewonder.com/robots/dash/

Some parts of the Dash robot that are not visible in the dia microphones, speakers, and Bluetooth connect to IOS, Android, and Kindle mobile devices.

***Lesson Implementation***

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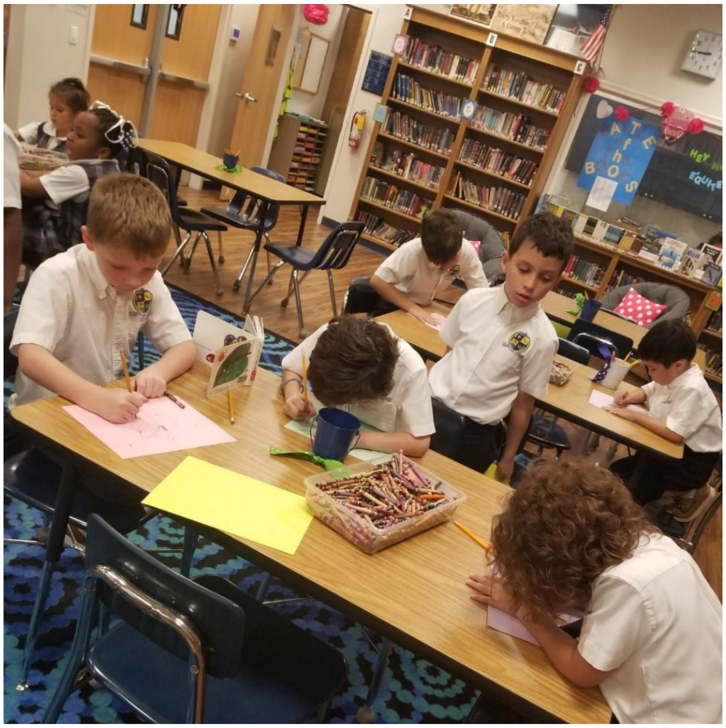
The robot used for this lesson was called Dash. The lesson took place in a media center comprised of a library and an adjacent computer lab. The lesson began with the technology teacher reading the book *The Very Hungry Caterpillar*, written and illustrated by Eric Carle in 1969, to the first-grade class of students. To reflect on the story, students were asked to recall the different stages of the hungry caterpillar's life: the egg, larva (caterpillar), pupa (chrysalis or cocoon), and adult butterfly. As each stage was identified, the teacher discussed its characteristics and reviewed pictures of them from the book. Once all four stages were identified, students were seated at four table groups (one for each stage) and equipped with drawing paper and crayons. Next, students were asked to create drawings of the life stage assigned to their table and draw a visual representation of it, as shown in Figure 2.

Figure 2. Students Drawing the Life Stages of the Caterpillar in the Story



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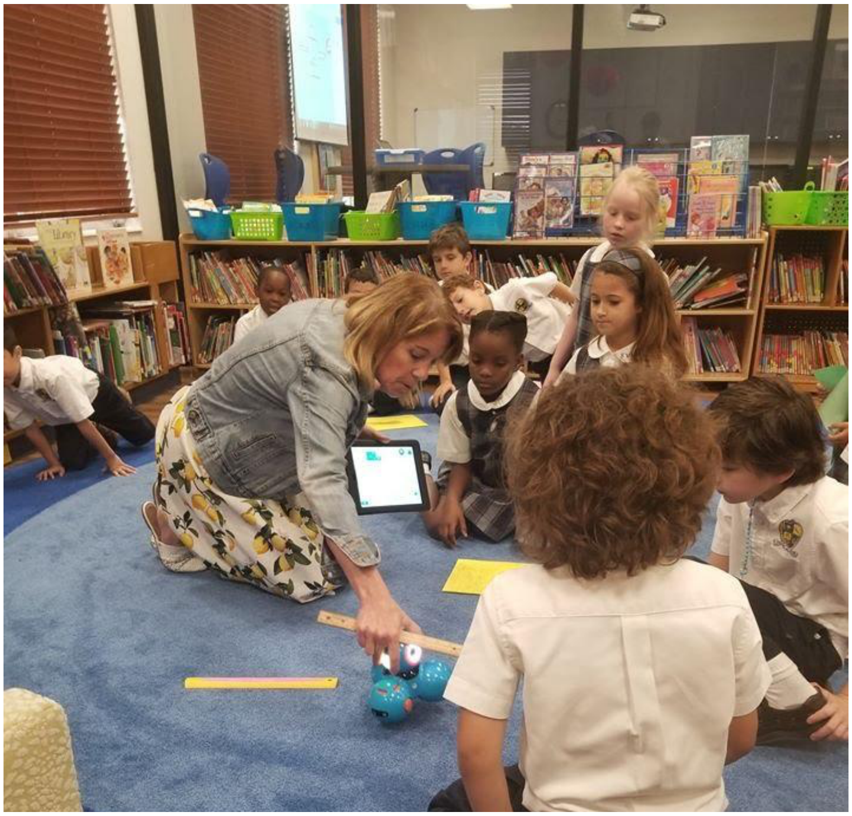
The teacher reinforced reading and science concepts through visual arts integration by asking the students to reflect on the life stage of the caterpillar in the story.

Once the students finished drawing, some of them stood up to share and describe their creations with the class. Then, the teacher collected one picture from each stage of the butterfly life cycle and directed the students to sit together in a circle on the floor on a large carpet, and introduced Dash the robot to the students. Next, she asked students to identify the first two phases of the butterfly life cycle and placed the drawings of them on the carpet. Then, the teacher asked a student to help measure the distance between the two pictures on the floor in centimeters, as shown in Figure 3.

Figure 3. Measuring the Distance Between Drawing in Centimeters



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Then, the teacher showed students how she could use block coding to program Dash to travel on the carpet from the first stage to the second. At each stage, a student volunteer recorded their voice, stating the name of that stage on the iPad. The process was repeated to program Dash to travel in a large rectangle around the carpet to all four stages and play the recording of the children saying the stage name upon arrival at each drawing.

***Adapting to Other Stories***

The suggested strategies were tailored to the story *The Very Hungry Caterpillar* (Carle, 1969). Children enjoy viewing brief videos of authors and illustrators at work, which provides modeling for how stories and artwork are created. Extensions or added resources for this children's book are included in Appendix A. The strategies for this example lesson can easily be adapted by teachers to other works of children's literature that involve sequencing of steps. Since students read the story and created drawings of each stage in the butterfly life cycle, which led to the programming of Dash, students could write and illustrate an adaptation of the storyline for other books. Examples of such books include:

- Bridwell, N. (1963). *Clifford the big red dog.* Scholastic.
- Carle, E. (1977). *The grouchy ladybug.* HarperCollins.
- Carle, E. (1995). *The very lonely firefly.* Random House.
- Cronin, D. & Lewin, B. (2001). *Click clack moo: cows that type.* Simon & Schuster.
- Keats, E.J. (1962). *The snowy day.* Viking.
- Martin Jr., B. & Carle, E. (1992). *Brown bear, brown bear, what do you see?* Holt.
- Numeroff, L. & Bond, F. (1985). *If you give a mouse a cookie.* HarperCollins.

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## Conclusions and Future Research

Teaching and learning strategies in each discipline of the STREAM model with an emphasis on art, reading, and technology assist teachers in planning instruction. Active engagement of students in the learning process can be supported in many ways, including the STREAM approach. There are many strategies that can be utilized when integrating visual art and reading and writing with STEM through the STREAM approach. As passionately stated by McClure (2017), "early STEM exposure is critical for later educational outcomes; when adults downplay its importance in the early years, they also diminish young children's current and future potential" (p. 214). Therefore, strategies that can be implemented with young learners are especially needed.

Research indicates that robots can be used by teachers to foster young learners' interest in STEM concepts (Varney et al., 2021) . According to Cheng et al. (2018), "The current state of the art of educational robots indicate an urgent need to explore the essential applications of such robots" (p. 400). At the same time, when we integrate technology, we must always be aware of our teaching goals and use them to achieve their point by point instead of just mixing and matching various technology tools to motivate or engage students (Xefteris, 2021). The lesson described in this study used the Dash robot with first graders to retell the story of *The Very Hungry Caterpillar*, but a less costly educational robot like the Sphrio Mini could easily be used in its place. In addition to switching up the technology, educators can choose different children's stories that involve a sequence of steps to create their own unique lesson plan.

Introducing young children to robots, coding, and "deep learning" are among the game-changing technologies that are altering how people think, learn, live and work. Moreover,

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exposure to STEM topics in early childhood is critical for later educational outcomes; failing to implement it may diminish young children's current and future potential (McClure, 2017). Therefore, now is the time for educators to seriously consider how technologies on the horizon will impact teaching, learning, and the world that awaits students in the coming years. By extending the approach to STREAM teachers can provide opportunities for young learners to express learning outcomes in STEM content through creative arts, reading, and writing while developing literacy skills across disciplines. The lesson presented here offers a simple and easily replicated, and adaptable model for educators to introduce STEM content through STREAM to young learners.

Another way to extend the reach of this concept is to bring the story and the robots out into the community to engage children and families in informal STREAM activities. For example, the teacher shown in this article has subsequently taken the robot to a family event in a rural area of western Palm Beach County to replicate the lesson with a population marginalized by poverty and less access to digital technologies. Future community-based STREAM events are in the planning phases to extend this research beyond the formal classroom education setting. Future research on how informal STEM activities that link STEM concepts to children's literature may explore how these experiences help children form STEM interest, knowledge, and identities while also examining intergenerational learning processes.

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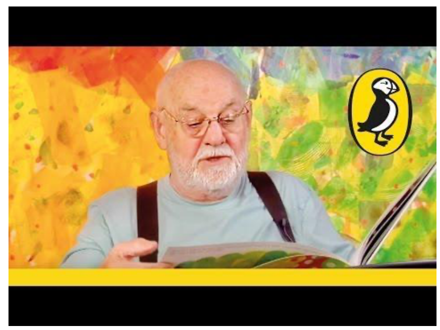
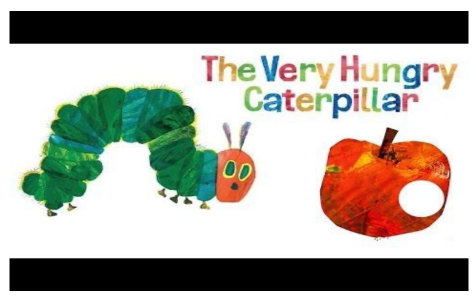
**Appendix A**

*Technology Resources for The Very Hungry Caterpillar*

| Resource Type | Description | URL |
|---|---|---|
| Video | Eric Carle reads The Very Hungry Caterpillar | https://www.youtube.com/watch?v=vkYmvxP0AJI  |
| Video | The Very Hungry Caterpillar - Animated Film (not read by Eric Carle but used often by teachers) | https://www.youtube.com/watch?v=75NQK-Sm1YY   |

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| | | |
|---|---|---|
| Video | The Very Hungry Caterpillar \| Eric Carle Creates 45th Anniversary Collage | https://www.youtube.com/watch?v=OCaFkD5xrXI  |
| Web page | This web page has a great photo of Carle in his "Messy" studio, which can appeal to young children. It's okay to get messy when being creative. | https://www.carlemuseum.org/about/about-eric-carle/artistic-process |
| Web page | The life cycle of a butterfly lesson plan | https://www.education.com/lesson-plan/life-cycle-of-a-butterfly/ |
| Worksheet | The life cycle of a butterfly worksheet | https://www.education.com/download/lesson-plan/life-cycle-of-a-butterfly/attachments/file_401792.pdf |
| Handout | Butterfly garden instructions | https://cdn.shopify.com/s/files/1/0075/6983/4020/files/Caterpillar_QG_2020_rev2_1.pdf?v=1586537101 |