

A photograph of two young children playing with large, light blue foam blocks in a classroom. A boy in an orange shirt is in the foreground, focused on building a structure. A girl in a pink shirt with a Minnie Mouse graphic is in the background, smiling and reaching up. The blocks are stacked and arranged in various ways, creating a playful environment.

Computer Science Unplugged

Second-grade students design a puppy playground using computational thinking.

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Computational thinking (CT) is a fundamental skill for all and not just for computer scientists. Computational thinking can provide a basis for problem solving, for making evidence-based decisions, and for learning to code or create programs. Therefore, it is critical that all students across the K–12 continuum—including students in the early grades—have opportunities to begin developing problem solving and computational thinking skills. With that in

mind, we have designed an engineering design activity to engage children in kindergarten through second grade in computational thinking (see Table 1 for a description of computational thinking competencies). This 30-minute play-based activity entails a task in which children create a safe play space for Eva’s puppy. The activity was implemented in an informal learning setting with the presence of adults. Adults apply strategies that aid children as they employ computational thinking throughout the task. This same activity can also be used in school settings.

Computational Thinking Integration

Computational thinking (CT) has been defined by researcher Jeanette Wing as involving “solving problems, designing systems, and understanding human behavior, by drawing on the concepts fundamental to computer science” (Wing 2006, p. 33). Although computational thinking is central



to computer science, CT skills, such as *abstraction*, *problem decomposition*, *algorithmic thinking*, *pattern recognition*, and *debugging* cut across multiple disciplines, promoting seamless integration in science and engineering (Wing 2016). Engineering design can be a context and approach for fostering computational thinking in formal and informal settings for elementary-age children. Through such learning experiences children can develop 21st-century skills vital for success in STEM+CT (science, technology, engineering, and mathematics, computer science) careers. In this article, we share an engineering design activity that we employed to engage kindergarten to second-grade students in STEM+CT.

Informal learning activities offer children enrichment opportunities that supplement traditional classroom learning, which is often limited by certain constraints. Informal settings also facilitate the development of engineering skills among K–12 students (Dorie, Cardella, and Svarovsky 2014). Engineering can support and promote computational thinking in elementary aged children as engineering design provides context (NRC 2011). We developed and implemented the 30-minute *Puppy Playground Challenge* activity (Figure 1, p. 58) to expose students to computational thinking in an informal learning setting and conducted research to examine children’s engagement in different CT competencies (Ehsan and Cardella 2017). The activity took place at a local science center in Indiana and was implemented during a second-

TABLE 1

Computational Thinking Competencies.

CT Competency	INSPIRE Definitions
Abstraction	Identifying and utilizing the structure of concepts/main ideas
Algorithms and Procedures	Following, identifying, using, and creating an ordered set of instructions (i.e., through selection, iteration and recursion)
Automation	Assigning appropriate set of tasks to be done repetitively by computers
Data Collection	Gathering information pertinent to solve a problem
Data Analysis	Making sense of data by identifying trends
Data Representation	Organizing and depicting data in appropriate ways to demonstrate relationships among data points via representations such as graphs, charts, words or images
Debugging/Troubleshooting	Identifying and addressing problems that inhibit progress toward task completion
Problem Decomposition	Breaking down data, processes or problems into smaller and more manageable components to solve a problem
Parallelization	Simultaneously processing smaller tasks to more efficiently reach a goal
Simulations	Developing a model or a representation to imitate natural and artificial processes
Pattern Recognition	Observing patterns, trends and regularities in data (Google)

FIGURE 1

Materials list.

Build a Safe, Puppy Play Space!

Can you help Eva and her Puppy?

Eva is a kindergarten student. She has a puppy. She wants to send him to play outside in the yard.



Oh no! The yard is not ready for the puppy to go and play.

Eva needs your help. She wants a space for the puppy that:

- keeps him from running away from the yard.
- has toys to help him play and get exercise.
- includes patterns to look nice.

Use the big blocks to build a safe play space for her puppy. We will send a photo of what you build to Eva.



grade class field trip to the science center. Several activities were set up for them to rotate through; one was the Puppy Playground, an informal play-based activity. Upon arrival to the science center, the students were reminded of the rules: no running or pushing, and to work with and respect each other. The students were then spilt into teams of four pre-determined by their classroom teacher and diverse in regard to gender and academic abilities. ESL accommodations were not necessary for this group of students, as all students spoke English. However, differentiation strategies were considered when designing and implementing the activity. The task was presented through a sign with large and simplified text and an image of a puppy. Moreover, the adults facilitated the activity by asking questions to make sure everyone in each group understood the task. Large foam blocks were set up in an open play area (Figure 2) in the science center. Children could easily access the blocks and build together.

As children engaged in designing their puppy playground, they employed skills such as teamwork, creative problem-solving, and effective communication to design the puppy playground. Additionally, to address the constraints in the activity (mentioned below), children applied multiple CT competencies such as problem decomposition, abstraction, pattern recognition, and algorithm and procedure to come up with their solutions.

Activity Implementation

The activity initiated with an adult reading the problem to the children. The problem required children to create a prototype of a puppy playground for Eva's puppy with the large foam blocks (See Figure 3 for examples of children's prototypes). This puppy playground needed to meet the constraints of:

- Keeping him from running away from the yard,
- Including toys to help him play and get exercise, and
- Including patterns to look nice.

Problem Decomposition

After the problem was read to the children, they were asked to decompose the problem by breaking it down into more manageable components to solve the problem. The adult guided the children through a problem scoping process by asking questions to help the children understand the problem and its constraints. The questions included, but were not limited to, "What is the problem that Eva needs your help with? What should the puppy playground include? How should Eva's puppy playground look like? Where should we start?" Children responded with short answers like "build", "a gate" or longer responses like "Build a playground for her puppy?" or "we can build a fence." They further elaborated that building a fence can make the playground safe and difficult for the puppy to run out. This illustrated that they understood the constraints and criteria of the problem that they were addressing. Additionally, presenting the idea of "building a fence" or "gate" showed that children could identify elements that should be a part of the playground, which is evidence of problem decomposition.

FIGURE 2

Big blue blocks.



PHOTOS COURTESY OF THE AUTHORS

FIGURE 3

Students work on building their prototypes.



Abstraction

After engaging in problem scoping and problem decomposition, the children began working on the design of their prototype through the use of abstraction: identifying and utilizing the main structure of concepts/main ideas that can be generalized to other contexts. In order to elicit abstraction, the adult guided children through this process by asking questions such as, *What makes a playground?* The children responded by identifying the various components found in the playground, like a “slide” or a “swing.” Then, to get children to think about the closed space required for the puppy playground, the adult asked *What else? What do we have in our backyard?* Children identified, “a wall all around.” Children began searching through the various blocks to locate shapes that would be appropriate to build the different playground elements. The children’s responses exhibited abstraction as they presented ideas connected to their real-life experiences of visiting playgrounds. They were able to filter out unnecessary details or characteristics of a playground and point to the main elements that should be included in their playground. For example, rather than focusing on the different things that can be unique to a particular playground, children focused on common playground features such as a slide or a swing.

Children also engaged in the CT competency of abstraction when going through the different shapes. They filtered

out unnecessary details of an object in their mind and associated it to a block or a combination of blocks. The adult helped to elicit abstraction by asking *What is the fence going to look like?* The children looked at the various shapes and stated, “a large rectangle.” Similarly, another child in the team said aloud that she would build the playground components to entertain the puppy. Then she found a curved block that would be appropriate for a ball slide (a ball can be dropped in and go down a slide), and the girl said, “I will do a slide (showing the block to her team).”

Pattern Recognition

One of the design constraints was that the puppy playground should include patterns to make it appealing. This is where children applied the CT competency of pattern recognition, defined as recognizing and identifying patterns or similarities within any data that helps to solve the problem. This is similar to the crosscutting concept of patterns in the *Next Generation Science Standards* (NGSS Lead States 2013) where patterns observed in nature guide classification and prompt questions about relationships.

The adult had children reflect on their design by eliciting their previous experiences of visiting playgrounds and/or playing or having a puppy. The adult asked, *How does a puppy come in or go out of the house.* A child responded, “through a gate.” These connections helped children engage



FIGURE 4

Small blocks.



in pattern recognition, as they were able to recognize the similarities seen across playgrounds they have visited before. These patterns were associated with children's experiences, which they applied to identify patterns in the toys they build for the puppy and the elements they included in the puppy playground.

Similarly, many children also connected their understanding of shapes and shapes of various objects and merged the two together to help elaborate on the patterns in their design. The adult asked, *How can we sort or organize these shapes?* Children looked through all the shapes and organized the blocks based on shape and size (additional pattern recognition). For, example, one member of the team grouped all the rectangular blocks in one pile and the cylinder blocks in another. This happened on several occasions during the design of the playground, which helped children to see what materials were available and helped the children to come up with ideas that included patterns to build the components of the playground.

Algorithm and Procedure

Another competency that was employed throughout the creation of the puppy playground structure was algorithm and procedure, which we defined as: identifying, using, and/or creating sequenced sets of instructions. Children created an

algorithm when lining up the rectangular blocks to build a closed spaced. Likewise, children employed the "algorithm and procedure" competency when following a procedure an adult suggested. For example, a child built a flower using the blocks for her puppy playground by following the instructions the adult provided. The competency occurred throughout the activity, especially when children were constructing their prototype.

Assessing Learning

There was no structured assessment conducted because the activity was conducted in an informal learning environment. However, the adult formatively assessed children's engagement in CT competencies and helped children evaluate their design by asking questions such as, *What were we supposed to build? Have you used any patterns? Do you think the puppy is safe? Why? Is the puppy going to have fun? What are the toys he can play with?*

These questions helped children assess their design and identify if they met the constraints. Through responding to these questions, children were able to recap what the problem was and describe how they solved it (problem decomposition), identify patterns (pattern recognition), discuss the different features and functions in the playground (pattern recognition and abstraction), and make decisions about whether their design met all the criteria. By the end of the challenge, most of the groups successfully built a playground for Eva's puppy that met all the constraints. A sample rubric is shared online for use in a classroom (see NSTA Connection).

Conclusion

In the 21st century, advancing computational thinking in young children has become increasingly important (Wing 2006). Hence, we need to expose children to activities that can promote and support their CT engagement. The Puppy Playground activity discussed in this article can be implemented in both formal and informal settings. Many schools have a similar set of big foam blocks for physical education classes or/and at recess time, or teachers can implement

this activity in their classroom using blocks smaller in size (see Figure 4).

As children are exposed to the different competencies of CT, the teacher can elaborate on CT by describing how computer scientists and engineers employ these competencies to solve problems.

Moreover, in thinking about using this activity in a school setting, we need to think about how the activity relates to instructional standards. The *Next Generation Science Standards* (NGSS) promotes the integration of engineering and computational thinking, and the activity can be mapped to the engineering design standards as well as computational thinking standards. At the same time, many states have also started to implement the Computer Science Teacher Association (CSTA) K–12 Computer Science standards. On page 62, we provide an example of how the NGSS standards can be aligned to this activity for an informal or formal lesson. It is our hope that this activity and structure can support teachers with creating similar tasks that can engage children in computational thinking and engineering design. ●

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NSTA Connection

Download the rubric at www.nsta.org/SC1019

Connecting to the Next Generation Science Standards (NGSS Lead States 2013)

Standard

K-2-ETS1 Engineering Design

www.nextgenscience.org/dci-arrangement/k-2-ets1-engineering-design

- The chart below makes one set of connections between the instruction outlined in this article and the NGSS. Other valid connections are likely; however, space restrictions prevent us from listing all possibilities.
- The materials, lessons, and activities outlined in the article are just one step toward reaching the performance expectation listed below.

Performance Expectation

K-2-ETS1-2. Develop a simple sketch, drawing, or physical model to illustrate how the shape of an object helps it function as needed to solve a given problem.

DIMENSIONS	CLASSROOM CONNECTIONS
Science and Engineering Practice	
Analyzing and Interpreting Data	Students ask questions about the task and break the task into a simple problem that can be solved.
Developing and Using Models	Students use prior experience of playgrounds and dog parks to develop a model of a puppy playground.
Disciplinary Core Idea	
ETS1.A: Defining and Delimiting Engineering Problems Asking questions, making observations, and gathering information are helpful in thinking about problems. Before beginning to design a solution, it is important to clearly understand the problem.	Students ask questions to help understand the problem and the constraints and identify the main problem to understand the expected solution.
ETS1.B: Developing Possible Solutions Designs can be conveyed through sketches, drawings, or physical models. These representations are useful in communicating ideas for a problem's solutions to other people.	Students create a model of a puppy playground.
Crosscutting Concept	
Structure and Function	Students identify a playground as a design object and express how objects in the structure are relatable to their function

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