Learning How to Think Like an Engineer: A Design-Based Research Study of Kid Spark Education's Curriculum in Kindergarten

August 2018

Presented by:
Caster Family Center for Nonprofit and Philanthropic Research

University of San Diego
SCHOOL OF LEADERSHIP AND EDUCATION SCIENCES
THE NONPROFIT INSTITUTE

About Kid Spark Education

The mission of Kid Spark Education is to help children (especially girls, children from low-income families, and minorities) prepare for a lifetime of learning about science and technology.

About The Nonprofit Institute's Caster Family Center for Nonprofit and Philanthropic Research

The Caster Center is housed within The Nonprofit Institute in the School of Leadership and Education Sciences at the University of San Diego. The mission of the Caster Center is to provide research, evaluation and consulting services that build the leadership and strategic and evaluative-thinking capacity of local nonprofits, as well as to be the leading source of information, data and research on the local nonprofit sector.

Project Team:

Tessa Tinkler, PhD
Senior Research Associate, NPI Caster Center

Aya Tore, MA
Research Assistant, NPI Caster Center

Meghan Kelly, MPA
Research Assistant, NPI Caster Center

Connelly Meschen, MArch
Administrative Coordinator, NPI Caster Center

Ida Rose Florez, PhD
CEO, Early Childhood System Solutions

Michael Lindsay, PhD
Adjunct Instructor, Department of Leadership Studies

Caster Family Center for Nonprofit and Philanthropic Research
The Nonprofit Institute
School of Leadership and Education Sciences
University of San Diego
www.sandiego.edu/npresearch

Acknowledgements:

The Nonprofit Institute's Caster Center would like to acknowledge the Chollas-Mead Elementary and Bayside Elementary teachers and administration, as well as Kid Spark Education's staff for their time and participation in the data collection process.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

> *"The students learned what engineers are; that there is a whole world of engineering out there; they won't be intimidated by it."*
>
> – Teacher

In January 2017, Kid Spark Education (Kid Spark), a nonprofit organization focused on creating engineering educational experiences for children, commissioned The Nonprofit Institute's Caster Family Center for Nonprofit and Philanthropic Research (NPI) at the University of San Diego to conduct a research study exploring the implementation of their early childhood curriculum (PreK-1) in public kindergarten classes. Kid Spark provides applied Science, Technology, Engineering, and Math (STEM) programs to elementary and middle schools and other youth-serving organizations. Each program consists of grade-level aligned curricula and Mobile STEM Labs that contain engineering materials such as construction blocks, wheels, and joints.

Previous studies examining the use of Kid Spark's curriculum in preschool settings found that adult mentors were an essential component in supporting young children through the curriculum. Given Kid Spark's interest in serving kindergarten and first grade classrooms where adult to student ratios are much larger than in a preschool setting, this study sought to identify the conditions necessary to implement the curriculum in an elementary school setting. This study was conducted in two phases between September 2017 and June 2018. In Phase 1, NPI researchers and teachers partnered through an iterative process to enhance the original curriculum, implement it in kindergarten classes, assess its strengths and weaknesses, and further refine the curriculum. In Phase 2, NPI researchers assessed the impact of the revised curriculum on student and teacher learning.

The analysis of data from teacher focus groups and interviews, classroom observations, and photographs of students' constructions provide evidence that implementing the revised curriculum impacted students' and teachers' development of a STEM identity. Students showed evidence of growth in building foundational STEM fluencies, engaging in science and engineering practices, and developing knowledge of the field of engineering. Teachers demonstrated increased self-efficacy and value for the teaching of engineering as well as increased knowledge in basic engineering concepts and practices.

Key Findings After Participating in Kid Spark's Revised Curriculum:

Students…

- Showed increased complexity and evidence of symmetry in their constructions.
- Developed spatial reasoning skills
- Progressed in their use of engineering practices such as hypothesis testing and problem solving.
- Increased their understanding and use of STEM vocabulary.

Teachers…

- Increased their self-efficacy and value for teaching engineering to primary grade children.
- Used STEM vocabulary and concepts with children through Kid Spark lessons.
- Reported wanting to use the Kid Spark curriculum next year with their kindergarten students.

Key Recommendations for Future Curriculum Development:

- **Utilize the revised curriculum's format and content** to guide the final development of the PreK-1 curriculum. In further refinement of the units/lessons, prioritize instruction around the engineering concepts and then align building activities with the concepts.
- **Develop training and support materials for teachers** that include background information on engineering concepts and practical tips for using the blocks. Teachers preferred a handout for the content knowledge and a video or handout for the construction tips.
- **Make minor revisions to the Kid Spark Mobile STEM Labs** including re-designing figurines to represent greater gender and ethnic diversity, ensuring there are enough blocks for each child to complete a build from a construction mat, and updating construction mats with high resolution images and step-by-step visual instructions.

NPI commends Kid Spark for its commitment to learning and growth through its ongoing support of research and evaluation of its educational programs. This study was initially born out of Kid Spark's desire to better understand the impact of its programs on young children, and has resulted in both an enhanced curriculum and compelling evidence of its impact on young children and their educators.

OVERVIEW AND BACKGROUND

As technological innovation has dramatically shifted the global workforce, PreK-12 schools are increasingly recognizing the need to focus on developing students' knowledge and competencies in science, technology, engineering, and math (STEM). These efforts have opened up new opportunities for students to acquire 21st century skills such as problem solving, critical thinking, and creativity. Most STEM curricula have focused on older children, yet recent developmental research suggests that young children not only have the capacity to learn and think like scientists,[1] but their free play actually mimics design processes in engineering.[2] As young children play with materials, they employ pre-engineering thinking—making hypotheses, observing phenomena, and conducting and refining experiments.[3] Research suggests that engaging children early in STEM when they are naturally interested in exploring and understanding the natural and constructed world is critical to maintaining a pipeline of children who have the interests and competencies to excel in STEM fields.[4]

In January 2017, Kid Spark Education (Kid Spark), a nonprofit organization focused on creating engineering educational experiences for children, commissioned The Nonprofit Institute's Caster Family Center for Nonprofit and Philanthropic Research (NPI) at the University of San Diego to conduct a research study exploring the implementation of their early childhood curriculum in public kindergarten classes. Previous studies examining the use of Kid Spark's curriculum in preschool settings found that adult mentors were an essential component in supporting young children through the curriculum.[5] Given Kid Spark's interest in meeting the unique needs of kindergarten and first grade classrooms where adult to student ratios are much larger than in a preschool setting, this study sought to identify the conditions necessary to implement the curriculum in a public school setting.

This study was conducted in two phases between September 2017 and June 2018. In Phase 1, NPI researchers and teachers partnered through an iterative process to enhance the original curriculum, implement it in kindergarten classes, assess its strengths and weaknesses, and further refine the curriculum. In Phase 2, NPI researchers assessed the impact of the revised curriculum on student and teacher learning. The guiding research questions are listed on the following page.

---

[1] Gopnik, A. (2012). Scientific thinking in young children: Theoretical advances, empirical research, and policy implications. *Science, 337*(6102), 1623-1627.

[2] Bagiati, A. & Evangelou, D. (2016). Practicing engineering while building with blocks: Identifying engineering thinking. *European Early Childhood Education Research Journal, 24*(1), 67-85. | Bairaktarova, D. Evangelou, D. Bagiati, A. & Brophy, S. (2011). Designing environments to promote play-based science learning. *Children, Youth and Environments, 21*(2), 212-235.

[3] Brophy, S. & Evangelou, D. (2007). Precursors to engineering thinking (PET), *Proceedings of the Annual Conference of the American Society of Engineering Education*. Washington, DC: ASEE.

[4] Eshach, H. & Fried, M. N. (2005). Should Science be Taught in Early Childhood? *Journal of Science Education and Technology, 14*(3), 315-336.

[5] Vazquez, O., Guarassi, I. & Carr, R. (2012). *Designing Curriculum and Building Minds: Developing Readiness for Science-related Skills and Dispositions*. San Diego CA: Center for Academic and Social Advancement, University of California, San Diego.

Guiding Research Questions

Phase 1: What are the conditions necessary to implement Kid Spark in a public kindergarten class?

a. What type of scaffolding is needed to implement Kid Spark in kindergarten?
b. What should be included in the curriculum for teachers to use it with minimal preparation?
c. What should training/professional development look like?

Phase 2: How does the revised Kid Spark curriculum facilitate student learning of engineering foundational fluencies and practices and teacher learning of engineering concepts and pedagogy?

This report begins with a brief description of Kid Spark programs and a summary of the methodology used for Phases 1 and 2. Next, the findings are reported in two phases. Phase 1 reports on the lessons learned through the process of refining the curriculum to be used in kindergarten classes. Phase 2 reports on the revised curriculum's impact on students' and teachers' learning after it was implemented in kindergarten classrooms during spring 2018.

Description of Kid Spark

Kid Spark's vision is for children to see themselves as designers of their world and for educators to develop into being confident STEM mentors. Kid Spark provides applied STEM programs to elementary and middle schools and other youth-serving organizations. Currently, Kid Spark offers four grade-level-aligned curricula that progress in complexity and are designed to be flexible enough to stand alone or build upon one another. Accompanying the curricula are Mobile STEM Labs containing construction materials. For the PreK-5 students, each Mobile STEM Lab is designed to serve four students and contains materials such as varying sizes of blocks, wheels, joints, and mini figurines. A public classroom typically purchases eight Mobile STEM Labs to accommodate 25-30 students. The four curricula available to schools and organizations at the time of this report are listed below. The revision of the PreK-1 curriculum, Foundational Fluencies, is the focus of this study.

Kid Spark Pk-8 STEM Programs	Grade Level
Foundational Fluencies Educators mentor students to develop foundational capacities prerequisite to all STEM learning, like spatial reasoning, problem solving, and symbolization.	**PreK-1**
STEM Fundamentals Students begin to develop STEM Identity & Technology Fluency while exploring applied mathematics, mechanical engineering, and robotics.	2-5
Applications in Design and Engineering Students explore challenging STEM concepts from their everyday world, authoring with technology to solve problems and create new solutions.	6-8
Systems of Technology Students learn to use multiple technologies to create system solutions. Explorations include: mechanical and structural engineering, computer aided design & 3D printing, programmable robotics, and integrated design challenges.	6-8

METHODOLOGY

The findings presented in this report are based on a comprehensive synthesis of multiple data sources collected between October 2017 and June 2018 in kindergarten classes at Chollas-Mead Elementary and Bayside Elementary in San Diego, California. Both schools shared similar demographics. According to the school profiles in 2016/2017, more than three-quarters of children came from low income families, eight out of ten were Hispanic-Latino, and roughly one-half of students were English language learners.[6]

Phase 1 Methods: Curriculum Development

NPI researchers employed a design-based research approach[7] to revise Kid Spark's early childhood curriculum. Design-based research is a practice-oriented approach in which educational interventions are designed and tested in real educational contexts. Between October 2017 and June 2018, the following data sources were used to gather ongoing feedback from teachers in order to design a curriculum that could be used in any public kindergarten or first grade class setting (see Appendix A for methods of analysis).

Table 1: Phase 1 Data Sources

Data Source	Participants	Description
Teacher Focus Group #1	n=5	In October 2017, NPI researchers conducted a focus group with five kindergarten teachers at Chollas-Mead to gather initial feedback about their impressions of the original Kid Spark curriculum, including strengths and areas for improvement.
Teacher Focus Group #2	n=5	In November 2017, NPI researchers conducted a second focus group with the same five kindergarten teachers to share revised curriculum and gather additional feedback on areas for improvement.
Curriculum Feedback Forms	n=5	During the spring of 2018, the five participating kindergarten teachers were asked to provide written feedback on the strengths and challenges of each of the lessons after implementing them in their classrooms. This feedback allowed NPI researchers to revise curriculum as it was being developed.
Teacher Focus Group #3/ Interview	n=6	In June 2018, NPI researchers conducted a third focus group and a telephone interview with one teacher from Bayside who had implemented the revised curriculum with her kindergarten class during an eight-week rotation. The focus group and interview were designed to gather feedback on the strengths and challenges of the curriculum, as well as overall impressions of Kid Spark.

[6] See School Profiles at http://www.ed-data.org/

[7] Anderson, T. & Shattuck, J. (2012). Design-based research: A decade of progress in educational research? *Educational Researcher, 41*(1), 16-25.

Phase 2 Methods: Kid Spark Impact on Learning

From January through June 2018, the following data sources were used by NPI researchers to assess the impact of Kid Spark's revised curriculum on students' and teachers' learning (see Appendix A for methods of analysis).

Table 2: Phase 2 Data Sources

Data Source	Participants	Description
Focused Classroom Observations	n=7 observations • 1 classroom • 26 kinder students (4 focus students)	From January 2018 through June 2018, NPI researchers conducted 7 classroom observations in a single classroom as teachers and students participated in structured Kid Spark lessons. The observations captured whole class activities and focused on a table of four students (two female and two male). One researcher used a rubric to code the observations for students' development of STEM fluencies and engineering practices and another researcher wrote ethnographic fieldnotes (see Appendix B for coding rubric).
Pre/Post Free Build Classroom Observations	n=10 observations • 5 classrooms • 128 kindergarten students	In January/February and again in May/June 2018, NPI researchers observed five classrooms as students participated in their first and last free build lessons (i.e., a lesson in which students could use the construction toys to build whatever they wanted). One researcher used a rubric to code the observations for students' development of STEM fluencies and engineering practices and one researcher wrote ethnographic fieldnotes (see Appendix B for coding rubric).
Photos of Kid Spark Constructions	n=56 matched pre/post photos • 112 photos • 5 classrooms	NPI researchers analyzed photos comparing students' first free build in January/February 2018 to their final free build in May/June 2018. Students who worked collaboratively on their free builds were excluded from the photo analysis. Photos were scored based on the construction's complexity, evidence of patterns, and elements of symmetry (see Appendix C for photo coding rubric).
Pre/Post Engineering Self-Efficacy Teacher Survey	n=5 teachers • 1 school • 10 surveys • 5 classrooms	In October 2018, NPI researchers sent an online 40-question pre-survey to five teachers asking them about their self-efficacy in teaching engineering, perceived value for teaching engineering, and demographics. In June 2018, teachers completed a post-survey asking the same questions. NPI researchers adapted the survey from the Science Teaching Self-Efficacy Belief Instrument.[8]
Teacher Focus Group/ Interview	n=6 teachers	In June 2018, NPI researchers conducted a focus group with Chollas-Mead teachers and a telephone interview with a Bayside teacher to gather information on teachers' perceptions of Kid Spark's impact on student and teacher learning.

[8] Riggs, I., & Knochs, L. (1990). Towards the development of an elementary teacher's science teaching efficacy belief instrument. *Science Education, 74*, 625-637.

PHASE 1: CURRICULUM DEVELOPMENT

NPI researchers revised Kid Spark's PreK-1 curriculum in order to make it more suitable for a public kindergarten class. The research team designed a process that would allow children and teachers' experiences with the revised curriculum to inform the kindergarten curriculum design. As each unit was implemented, information from classroom observations and teacher feedback were used by the research team to modify future units. Information gathered through this iterative process affected changes such as the length of lessons, the amount of pedagogical support provided to teachers, and the content of teaching aids (e.g., vocabulary lists).

The revised curriculum was informed by literature in early childhood science and math instruction, especially research on the relationship of spatial reasoning skills to long-term achievement[9], and developmental math progressions. To the degree possible, lessons were created to align with Next Generation Science Standards (NGSS). Lessons align primarily with NGSS science and engineering practices and crosscutting concepts because there are limited NGSS disciplinary core ideas and performance expectations at the kindergarten level.

Both the original and revised curriculum contained the same construction materials (i.e., blocks) but in the revised curriculum, the construction mats (i.e., step-by-step building instructions) included constructions that were easier for small hands to assemble. The NPI research team, in collaboration with kindergarten teacher participants, revised the original curriculum to include the following elements listed in Table 3 (see Appendix D for the full revised curriculum).

Table 3: PreK-1 Original vs. Revised Curriculum

Original Pre K-1 Curriculum	Revised PreK-1 Curriculum
• Instructors Guide that includes: ○ Teacher Tips ○ Visual list of materials ○ Information on how Kid Spark builds STEM fluencies • 10 Construction Mats	• A 16-lesson sequenced curriculum with four themed units that progress in difficulty • Culminating free build lesson at the end of each unit for students to practice their skills • Unit alignment to Next Generation Science Standards (NGSS) and Common Core Math standards • Student learning objectives, vocabulary lists, recommended children's literature, and classroom organizational tips for each unit • Scripted language for teachers to follow for each lesson that includes engineering vocabulary and activities to explore concepts • Supplemental learning extensions

[9] Wai, J., Lubinski, D., & Benbow, C.P. (2009). Spatial ability for STEM domains: Aligning over 50 years of cumulative psychological knowledge solidifies its importance, *Journal of Educational Psychology, 101*(4), 817-835. Zhang, X. (2016). Linking language, visual-spatial, and executive function skills to number competence in very young Chinese children. *Early Childhood Research Quarterly, 36*, 178-189.

Key Takeaways from Curriculum Development

Through the process of developing, refining, and implementing the curriculum, NPI researchers identified strengths and challenges around training and support, the Kid Spark construction system, and curriculum design. These lessons learned can inform the final version of the PreK-1 curriculum, as well as all Kid Spark curriculum development.

Training and Support

Teachers felt the revised curriculum's sequenced and scripted format enabled them to implement the lessons with minimal support. Teachers participated in a Kid Spark-led in-person training before the curriculum revision process began and felt they benefitted from the introductory lesson. However, they also felt that with additional written and video support materials, they could implement the curriculum without in-person training. Teachers identified the following additional needs:

Additional Support Needs

- **More content knowledge on engineering concepts**: Teachers expressed a lack of confidence in their ability to teach concepts such as gravity, motion, reinforcements, etc. They suggested including background information with simple explanations for the concepts covered in each unit. Teachers referenced another STEM curriculum they had used in the past (FOSS Kits) as providing exemplary content knowledge to teachers.
- **Tips and tricks on using the blocks**: Some of the curriculum revisions NPI researchers made included tips on how to connect and disconnect blocks. Teachers felt these tips were extremely helpful and suggested a handout or video with practical tips on how to support students in using the blocks. Included in this would be an explanation of the functions of each of the blocks in the Mobile STEM Lab.

Kid Spark Mobile STEM Labs

The revisions to the original curriculum impacted the way teachers used the Kid Spark engineering materials and as such teacher feedback and research observations suggested the following areas for improvement:

Areas for Improvement

- **Organization of the Mobile STEM Labs not aligned with the revised curriculum**: In the original curriculum, each table of four students had access to a Mobile Stem Lab, complete with all blocks. The revised curriculum introduced each of the blocks gradually in order for students to develop competency using the blocks before advancing to more difficult builds. In this way, the curriculum was scaffolded without needing the one-on-one mentorship required with the original curriculum. In order to manage the classroom and scaffold the lessons appropriately, teachers felt they needed to organize the blocks by type and only give students access to the blocks necessary for each lesson. This could potentially make it difficult for different grade-levels to share the Mobile STEM Labs.
- **Uncertainty of each block's function**: Many blocks were included in the Mobile STEM lab but there was no information on their function. Teachers would like to be able to explain the function of each block.

- **Lack of blocks**: There were not enough blocks for every student to independently complete some of the builds. This was the case for the *Unit 3, Lesson 2 – Long Haul*, *Unit 4, Lesson 1 – The Caterpillar in Imagination Land*, and *Unit 4, Lesson 4 – The Helicopter*. Even for those lessons in which each child could build their own model, there were no extra pieces in case a block broke or was lost.
- **Fingers got stuck in blocks**: Little fingers got stuck in the blocks multiple times. Students had to use soap and water to slip their fingers out of the openings.
- **Broken blocks**: Over the course of the 16-week session 5 blocks were broken.
- **Construction mats difficult to follow**: The pictures on the construction mats were poor quality and it was very difficult to discern the direction of some of the blocks. Also, some of the steps were combined and the arrows which were intended to help clarify actually confused students and teachers.
- **Figurines not representative of the diversity of public school students**: Each Mobile STEM Lab included mini figurines that are intended to look like engineers, and the figurines all appeared to have white skin. Children immediately gravitated to the figurines because it allowed their constructions to become back drops for their play. Given their critical importance to the students' experience, and Kid Spark's mission to make engineering accessible to underrepresented groups, it is important the figurines model the ethnic and gender diversity of public school children.

Kid Spark Curriculum Design

The revised curriculum allowed kindergarten teachers with little to no adult support in the classroom to implement it to a classroom full of children, many of whom were in transitional kindergarten, spoke limited English, or had a special education designation.

Main Findings for the Ongoing Refinement of the Curriculum

- **Collaboration both a strength and a challenge**: Developmentally, young children do not share well when their own self-interest is at stake.[10] Consistent with this, students struggled to collaborate when they were supposed to build a model together because there were not enough blocks for them to build their own. However, when students participated in a free build or when the lesson contained a particularly difficult model, they often elected to collaborate. Building collaboration into the lessons allowed students to practice an important skill, yet collaboration worked best when it was mutually beneficial to both/all students.
- **Teachers utilized as resources**: At Chollas-Mead, the entire kindergarten team implemented Kid Spark in their classrooms. This allowed them to share resources (e.g., one teacher made vocabulary cards and all teachers used this resource) and plan more effectively. Teachers reported discussing the lessons during their team planning and agreed that working as a team made the lessons successful.
- **Teachers' heavy reliance on the scripted language in the revised curriculum**: Teachers had very little prep time and often seemed to be reading the lesson instructions for the first time with students. Teachers reported that having the script allowed them to facilitate the lesson with minimal preparation.

[10] Smith, C.E., Blake, P.R. & Harris, P.L. (2013). I Should but I won't: Why young children endorse norms of fair sharing but do not follow them. *PLoS ONE* 8(3): e59510. https://doi.org/10.1371/journal.pone.0059510

- **40+ minutes needed for more difficult lessons:** In the early lessons, students were introduced to one block at a time and a 20-25 minute block of time was adequate. However, for Units 2-4 teachers needed more time to complete a lesson. At Bayside, where the teacher had three 25-minute blocks of time per week, the teacher either took two sessions to complete one lesson or repeated the lesson two times in one week to ensure students could complete it.
- **Implementation of the curriculum unique for each teacher**: Some teachers shifted between small and large group instruction throughout a lesson whereas others had students in their small groups during all lessons. While the management of students is likely best left up to teachers, it seemed that certain difficult steps or skills were best explained in a large group where the teacher could demonstrate how to accomplish a given task to the whole class at one time.
- **"Free Builds" well-liked and afforded children opportunities to be creative, problem-solve, and collaborate**: Each unit concluded with a free build in which students had access to all materials and could build as they wish. Teachers reported that students enjoyed these sessions and whenever there were any gaps in time during the other lessons, students would initiate their own free build.
- **Opportunities to refine units/lessons:** There was limited time to fully develop the curriculum so that each unit had a clear organizing theme. Having cohesive themes will ultimately strengthen the curriculum's alignment with science and math standards.

Overall, teachers were very enthusiastic about their experience implementing the curriculum and felt it served as an excellent introduction to engineering for both themselves and their students.

PHASE 2: KID SPARK IMPACT ON LEARNING

Impact on Student Learning

Through participation in the revised Kid Spark curriculum, students were introduced to and given the opportunity to practice many of the cross-cutting concepts and science and engineering practices that make up the K-12 Science Education Framework,[11] the guiding framework for the science standards adopted in more than two-thirds of the United States.[12] Based on an analysis of classroom observation data, scoring of students' free builds at the beginning and end of the curriculum, and teacher feedback, the revised curriculum supported students' development of foundational STEM fluencies, afforded opportunities to use engineering practices, promoted social-emotional development, and introduced students to the field of engineering.

Developing Foundational STEM Fluencies

Data analysis suggests that as students progressed through the 16-week curriculum, they exhibited increased complexity in their building and improved spatial awareness. The curriculum also provided students opportunities to practice the NGSS cross-cutting concepts of patterns; scale, proportion, and quantity; and structure and function.

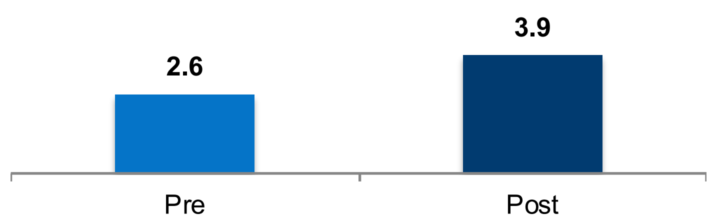
Evidence from Pre/Post Free Builds

Complexity and symmetry increased after participating in Kid Spark curriculum

Evidence of student growth in the development of foundational fluencies comes from an analysis of students' first (pre) and last (post) free builds. Students' free builds were photographed and scored based on a rubric that coded each construction's complexity, pattern-making, and symmetry (see Appendix C). Each element of the rubric was summed to create a total score for each of the pre and post constructions. As Figure 1 shows, students' total scores significantly increased from pre to post. Students' constructions demonstrated increased complexity and symmetry after participating in the Kid Spark curriculum. Making patterns did not change, however this is likely because each block type has a different function; thus, making easily recognizable patterns based on color or shape would not necessarily coincide with more complex uses of the blocks.

Figure 1: Average Pre and Post Free Build Score (n=56)*

(Scores could range from 0 to 6.5)



** Statistically significant difference* (p<*.05)*

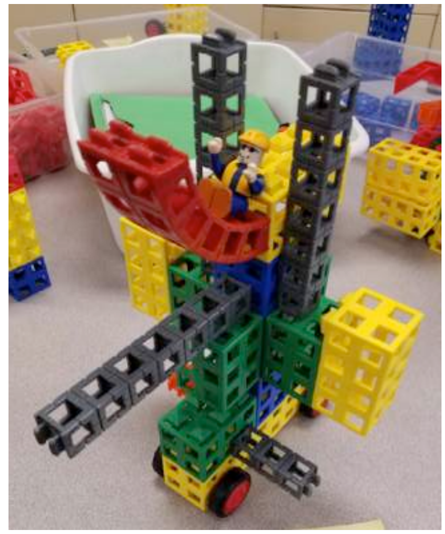
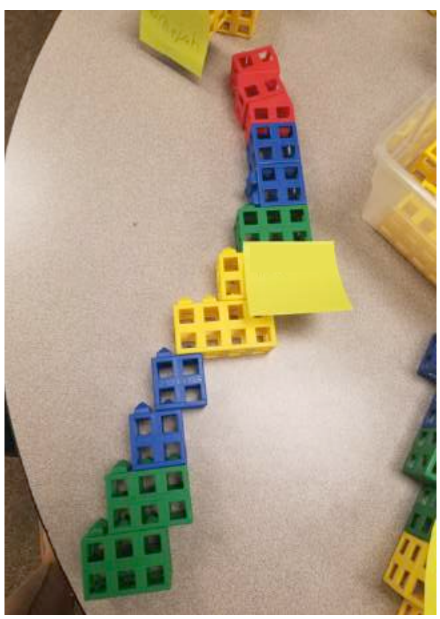
---

[11] National Research Council. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas. Committee on a Conceptual Framework for New K-12 Science Education Standards*. Washington, DC: The National Academies Press.

[12] The Next Generation Science Standards (NGSS) have been adopted in 19 states and 19 other states have developed their own standards, all of which are based on the K-12 Framework for Science Education. For more information, see http://ngss.nsta.org/About.aspx.

Figure 2 exemplifies the growth in the complexity of students' constructions over time and demonstrates how students used symmetry, progressed from designing mostly 2-dimensional structures to 3-dimensional structures with internal space, and built increasingly functional constructions with structural integrity that resembled actual objects. Additionally, the revised curriculum allowed students to explore the relationships between structure and function, one of the cross-cutting concepts in the K-12 Science Education Framework.

Figure 2: Side-by-Side Comparisons of Students' First and Last Free Builds

	First Free Build	Last Free Build
Student 1 Final construction shows improved symmetry and is 3-dimensional		
Student 2 Final construction shows structural integrity and a visible function		

Spatial Awareness

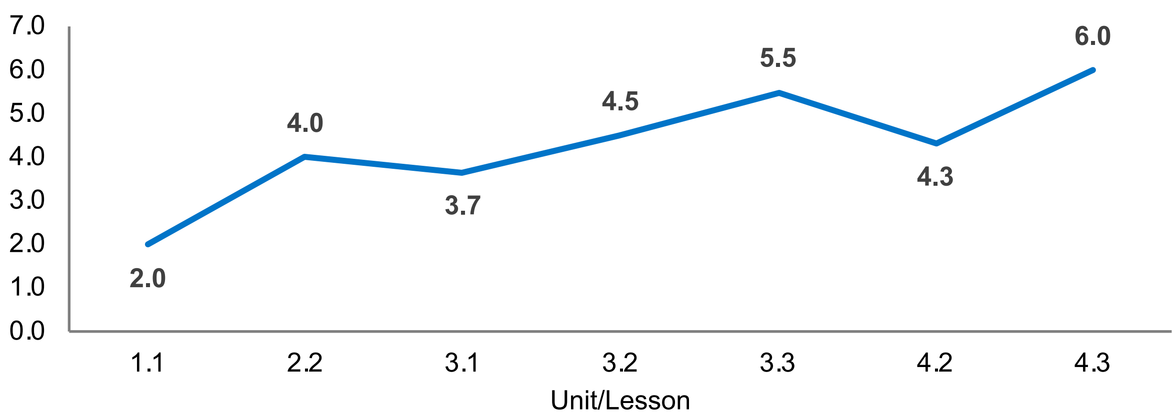
> *"They [developed] the skills that [have] to do with putting things together, spatial relationships."*
> – Teacher

Spatial reasoning refers to the set of skills involved in being able to mentally picture and physically manipulate objects. Spatial skills include being able to think about how objects look when rotated, how objects look from different perspectives, how parts of an object fit together, and how to construct a 3-dimensional object from a 2-dimensional model. Developing spatial awareness in early childhood is critical to the development of students' mathematical skills,[13] and research suggests that the ability to reason spatially is a strong predictor of achievement in STEM disciplines.[14] During the Kid Spark lessons, students demonstrated increased evidence of <u>mental rotation</u>, recognizing and using <u>symmetry</u>, and <u>building a 3-dimensional object from a 2-dimensional model</u>.

> **Students Demonstrated Increase in:**
> Mental Rotation
> Using Symmetry
> 2D model ➡ 3D object

One table of four students were observed during seven of the structured lessons (vs. free builds) to assess what and how they learned by participating in the revised curriculum. In order to assess students' spatial reasoning skills, observers coded every time students demonstrated mental rotation or symmetry. For each opportunity a student had to demonstrate one of these skills, the observer coded how clear the evidence was that the student successfully demonstrated the skill (0=no evidence to 2=clear evidence). Each lesson was also given a complexity score to account for the difficulty of the lesson (see Appendix B for rubric and complexity scores for each lesson), and the complexity score was then added to each student's highest daily symmetry and mental rotation score. As Figure 3 shows, while there were spikes and dips, on average, students increased their spatial reasoning skills from the first to the last lesson.[15]

Figure 3: Average Student Score of Spatial Reasoning Across Lessons (n=4) *(Possible student scores ranged from 0-6.5)*



[13] Cheng, Y. L., & Mix, K. S. (2014). Spatial training improves children's mathematics ability. *Journal of Cognition and Development, 15(1),2-11.*

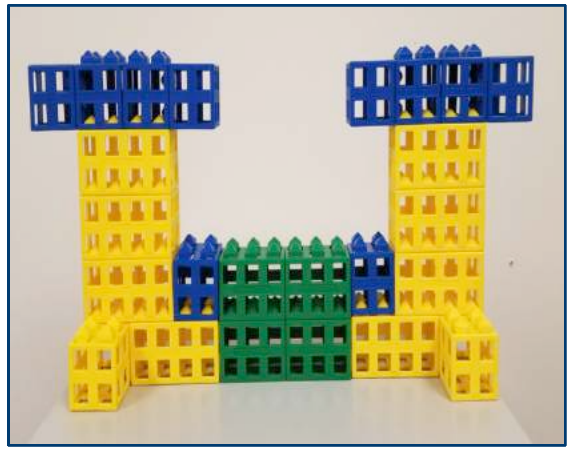
[14] Wai, J., Lubinski, D., & Benbow, C. P. (2009). Spatial ability for STEM domains: Aligning over 50 years of cumulative psychological knowledge solidifies its importance. *Journal of Educational Psychology, 101*, 817–835.

[15] Without the addition of the lesson complexity scores, students increased their mental rotation and symmetry scores from the first to the last lesson.

Symmetry in Action

Many of the structured lessons required students to use symmetry to successfully construct their model. One such example was in *Unit 3, Lesson 3 – Make Your Castle Strong*, in which students built a castle wall. The students were organized into pairs and each student was responsible for building one half of the castle wall. This lesson required students to build symmetrically in order to properly connect the two halves of the wall.

Field Note Excerpt



The teacher tells students the two halves will be symmetrical and asks if kids remember the word symmetrical.

SEVERAL KIDS: Yes.

Teacher is demonstrating how to build Part 1 piece-by-piece.

TEACHER *(to kids)*: See what I did?

Boy points out that the blue blocks on top are symmetrical.

The kids go to their tables and Student 1 (S1) and Student 2 (S2) are building together.

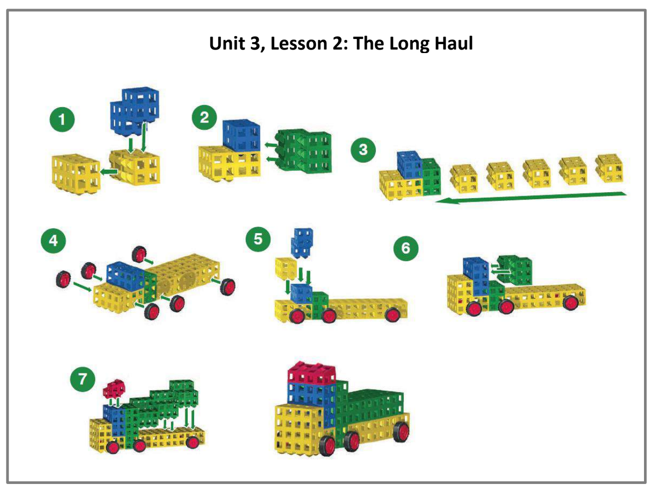
S2: I do it! I do it!

(S1 & S2 finish first half of castle and start building Part 2 together).

S1: I can help you. It's ok, it just has to be like the same.

(S1 is showing S2 how to fix yellow blocks and connecting the blue blocks on top.)

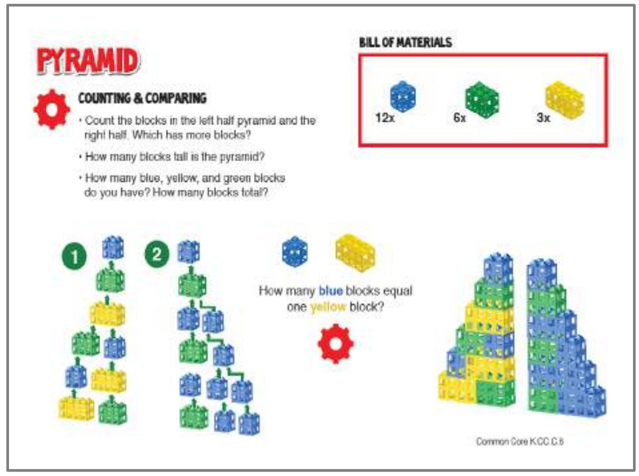
Sequencing



Sequencing is a fundamental planning skill in kindergarten covered in both language arts (e.g., logical order of storytelling) and math (e.g., ordering numbers). In seven of the lessons, students were required to use sequenced construction mats to build 3-dimensional objects. The coded data on the four focal students did not show clear evidence of growth in sequencing across lessons because two students successfully followed the sequence on the construction mats from the very first lesson and two of the students were unable to follow the sequence correctly on any of the lessons. However, the field note data showed many instances of students practicing sequencing and then problem solving when they did not correctly follow the sequence. Additionally, the students became competent at using the sequenced construction mats and during the final free build, some students chose to build with the construction mats instead of building their own constructions.

Pattern-Making

Identifying and making patterns is both a foundational mathematical skill and a cross-cutting concept in the K-12 Science Education Framework. Early lessons in the revised curriculum lent themselves best to pattern identification and pattern-making. In particular in *Unit 2 Lesson 2 – Patterns and Pyramids*, students used blocks to make repeating patterns and then collaborated to build a pyramid that contained patterns in the block type. Teachers had students practice making patterns, build the pyramid, and then discuss the use of patterns in the pyramid. The following field note excerpt describes the beginning of the lesson, in which one of the teachers introduced the concept of patterns.



Field Note Excerpt

TEACHER: Today we're going to talk about patterns *(she grabs yellow, blue, & green blocks)*. I made a blue, green & yellow pattern. Can I do it again?

> *Teacher used a chair up front to line blocks up next to each other – 6 blocks in a pattern of blue, green, yellow. Teacher asks one boy to share with the class what he just said.*

BOY: They are small, medium, and big.

TEACHER: That is another pattern.

> *She has all kids say the new pattern out loud three times.*
>
> *Teachers ask kids how many pyramids are on each block – kids shout out different answers. Teacher has kids say "4, 6, 8" as a pattern out loud three times.*

TEACHER (*looking at paper*): Could we make a different pattern with these blocks?

KIDS: Yes!

> *The students go to their tables and practice making their own patterns. Then they come back together at the front of the room.*

TEACHER (*asks a kid*): Can you tell me what the pattern is?

BOY: Blue, yellow, green.

TEACHER: Did he do it over again?

KIDS: Yes.

Developing Engineering Practices

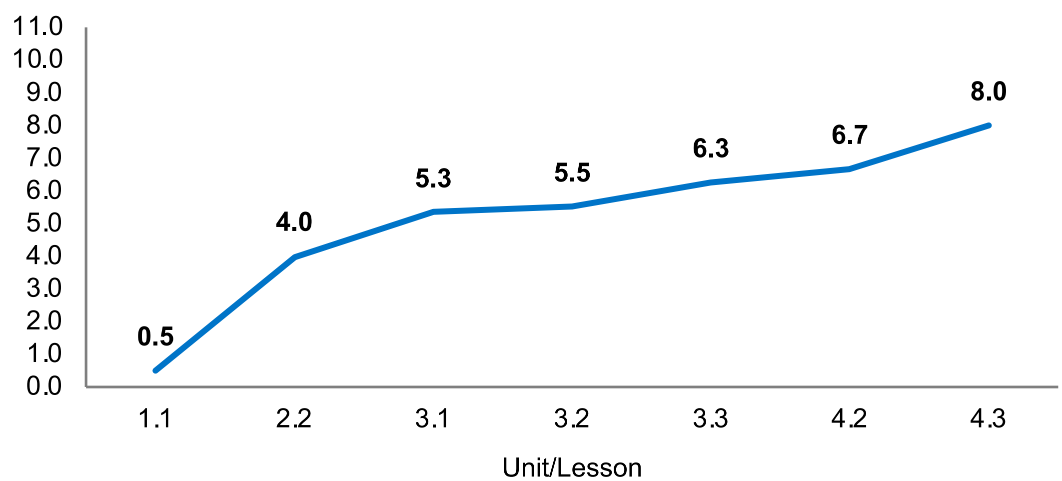
Studies of young children's play have identified ways in which their play imitates engineering practices. Based on NGSS Kindergarten Engineering Design Standards[16] and the K-12 Science Education Framework, observers coded classroom observations for the following engineering practices: gathering information, explaining how things work, problem solving, and hypothesis testing. Students progressed in their engineering thinking throughout the lessons.

> *"I think they learned problem solving. Whenever they would build they would find ways to make it better. Instead of getting mad, they liked making it better."*
> – Teacher

As students progressed through Kid Spark lessons, there was more evidence of their engineering thinking

Using the same methodology as was used to assess students' development of spatial reasoning, for each opportunity a student had to demonstrate one of these skills, the observer coded how clear the evidence was that the student successfully demonstrated the skill (0=no evidence to 2=clear evidence). Each lesson was also given a complexity score based on how difficult the lesson was to accomplish, and the complexity score was then added to each student's highest combined "engineering practices" score for each lesson in order to compare changes over time (see Appendix B for rubric and complexity scores for each lesson). As Figure 4 shows, students showed more evidence of engineering thinking as they progressed through the lessons.[17]

Figure 4: Average Student Scores of Engineering Practices Across Lessons (n=4)
(Possible student scores ranged from 0-10.5)



[16] California Department of Education. NGSS Kindergarten Disciplinary Core Ideas Standards. https://www.cde.ca.gov/pd/ca/sc/ngssstandards.asp

[17] Without the addition of the lesson complexity scores, students progressed in employing engineering practices from the first to the last lesson.

Explaining How Things Work

There were many instances of students explaining what their construction was and what it was designed to do. In *Unit 4, Lesson 3 – Helicopter*, the teacher prompted students to explain how the helicopter flew.

Fieldnote Excerpt

Teacher holds a helicopter up in front of the kids.

TEACHER: Does this have wheels?

KIDS: No.

TEACHER: How is it going to move without wheels?

BOY 1: By flying.

TEACHER: How?

BOY 1: With the wind.

GIRL 1: It's gonna move when people drive it.

GIRL 2: They have things in the back. *(referring to the rotor)*

TEACHER: What do they *[the rotor]* do?

KID: Spin.

TEACHER: That is called a rotor.

Teacher demonstrates a completed helicopter. Kids then go to their tables and build a helicopter. After they are done, they all gather at the front of the room.

TEACHER: The helicopter will fly through the air and gravity won't pull it down. What keeps it from pulling it down?

BOY 1: Engine.

TEACHER: Think about what you just added to your helicopter.

Girl holds the helicopter and starts pointing to all the pieces that were just added to make the rotor.

TEACHER: What are they called?

SOME KIDS *(mumbling quietly, sounds like):* Motors.

Teacher says rotors and has kids repeat

In this field note, the classroom discussed how helicopters work but the teacher did not accurately explain how a rotor keeps the helicopter in flight even with the force of gravity. This particular teacher commented during the focus group that she wished she had more knowledge to explain the science and engineering concepts they covered in the lessons. This is one area for improvement in the revised curriculum.

Problem Solving

Students demonstrated many instances of problem solving, sometimes with their teacher's assistance, other times with the help of a peer, and sometimes unassisted. Interestingly, instances of problem solving occurred most frequently during students' free building.

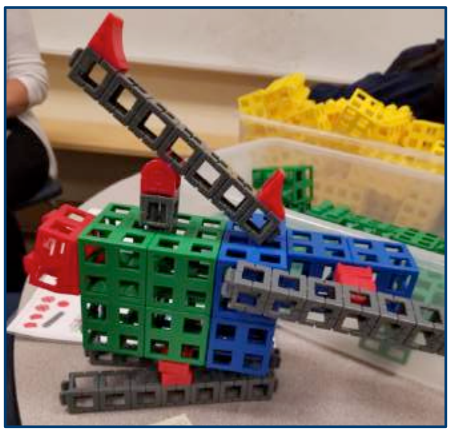
Fieldnote Excerpts from Free Builds

Student 4 adds one yellow to the bottom of his tower and tries to stand it up.

It doesn't stand (it is unbalanced and too heavy on one side).

He flips it over and it stands.

Problem solving occurred most frequently during free builds



Student 3 (S3) attaches one leg to bottom middle of helicopter.

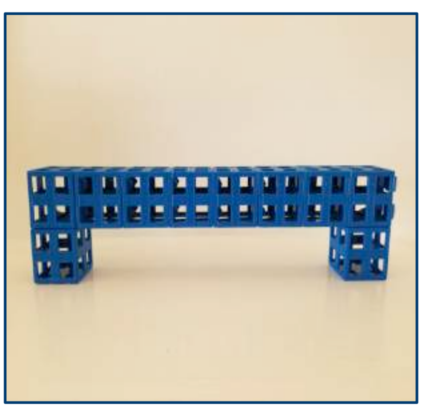
S3 tries to stand up helicopter on table and it falls over.

She picks it up and tries to attach another leg right next to the first one.

Helicopter stands up (though legs are not in correct position).

Hypothesis Testing

A few of the lessons were intentionally designed to encourage students to test the functionality of their constructions and experiment to make them stronger. One example of this was *Unit 3, Lesson 1 – How Much Load Can it Hold?* in which students built bridges, tested their integrity, and then reinforced the bridge to withstand increased weight.



Fieldnote Excerpt from Bridge Lesson

Student 3 (S3) is mostly watching.

Student 4 (S4) adds yellow blocks on either side of blue blocks. S4 adds five blue blocks - four are under yellow (looks symmetrical) and one in middle of original blue bridge.

S4 puts it on his chair and tries to sit on it.

S4: It doesn't break! Powerful, powerful.

S3 is just watching and occasionally says "no" to S4.

Developing Social Skills

Kindergarten is as much a time for academic preparation as it is for social-emotional learning, and young children learn primarily through play. Kid Spark's emphasis on play afforded students many opportunities to learn to work together and, according to teachers, it engaged students with special needs in critical ways. For example, teachers reported that some of their students who typically presented behavioral challenges remained engaged during Kid Spark activities. Likewise, teachers felt students' communication skills improved which is essential for English Language learner students who benefit from talking with their peers and teachers in English.

According to teachers, emphasis on play helped keep special needs students engaged

> *"[My students] grew. Looking at free builds we did – in the last one a lot of them worked together…whereas before it was more 'this is mine' – Their social skills and their communication skills grew because they were having to talk to each other."*
>
> – Teacher

The revised curriculum embedded many opportunities for children to collaborate, and observations revealed instances in which children became mentors, asked each other for help, and worked together through difficult tasks. There were also just as many instances where students fought with each other or a less capable student gave up and disengaged while the more capable child completed the task independently.

An Instance of Successful Collaboration

Two of the focal students (two girls) were paired together throughout the 16-week curriculum implementation. One of the students, "S1", was a very capable child who was able to successfully complete most of the Rok Bloc tasks and served as a mentor for her partner, "S2". S2 had a special education designation and struggled to correctly follow the construction mats. Although she showed evidence of mentally rotating objects and building 3-dimensional structures, she was only able to produce an exact replica of the builds with support from S1. Their partnership served them both because S1 was able to be a peer mentor and S2 was able to accomplish tasks she would not have been able to do on her own.

Field Note Excerpt of Two Children Building a Truck using a Construction Mat:

S2 starts connecting yellow blocks to each other, S1 stops her and says she thinks they go "back here" (pointing to other end), S2 agrees and pulls them off.

Girls are struggling to get yellow blocks connected.

S1 *(attaching 1 yellow)*: Like that.

S2 *(adding more yellow blocks – five total)*: Gimme wheels.

S1 counts the wheels on the instruction sheet (counts to six)

S2 starts to put on a wheel and S1 says wait and shows her that the blocks are starting to disconnect.

S1 pushes them back together.

S2 starts attaching wheels (not in the correct spots).

Instances of Challenges with Collaboration

The other two focal students (two boys) were also paired together throughout the curriculum, yet they struggled to work together. Similar to the other partnership group, S4 was a strong builder and could successfully follow the construction mats whereas S3 was not as strong of a builder and was often frustrated. Although there were instances in which S4 mentored S3, there were many times he would take over and complete a build independently.

Field Note Excerpt of Two Children Building a Bridge:

S3 is just watching and occasionally says "no" to S4.

Around the room kids are adding more blocks and trying to stand on structures.

S4: We made it.

S3 *(looks upset)*: I didn't make it!

For young children, curriculum should foster opportunities for students to independently create while also encouraging collaboration

These struggles with collaboration highlight the need for teachers to carefully plan groupings and reassess throughout the curriculum implementation to ensure all students are given opportunities to build their skills. Navigating challenges around sharing and working together is not new terrain for kindergarten teachers, but it is essential that the curriculum fosters developmentally appropriate opportunities for collaboration in which students can learn to work together while also being able to build independently.

Learning about the Field of Engineering

What is an Engineer?

One of Kid Spark's primary goals is to inspire children to see themselves as engineers in hopes of ultimately increasing the number of students seeking engineering careers. In light of this vision, the curriculum was revised to include descriptions of the various types of engineers and what engineers do. Students demonstrated their understanding of engineering through class discussions about the work of engineers. The following field note excerpts illustrate students' expanded understanding of the field of engineering.

> *"The students learned what engineers are; that there is a whole world of engineering out there; they won't be intimidated by it."*
>
> – Teacher

Field Note Excerpts from Class Discussions

Teacher reminds the students that last time they were in the room they talked about what engineers do and asks if anyone remembers.

A FEW KIDS *(yell out)*: They build things.

TEACHER: Why?

BOY: To solve problems.

Students demonstrated their understanding of engineering through class discussions about the work of engineers

In a previous lesson, students were instructed to become various types of engineers and build for an Imaginary Land. They learned about automotive engineers, marine engineers, and toy engineers.

TEACHER: We've learned about engineers – what do we call the ones who build cars?
BOY: Automotive engineers.
TEACHER: The kind who build ships & boats?
(kids do not seem to know, Teacher finally tells them - marine engineers)
TEACHER: Today we're going to be aircraft engineers – what do they build?
BOY: Airplanes?

Teachers reported that their students now knew what engineers were and one teacher said some of her students called themselves engineers as they were constructing with the Rok Blocs. Another example came during the final focus group interview. A teacher shared an example of how she was able to relate their Kid Spark lessons to a real-world application.

> *"One example was we went to the zoo.*
> *I was all excited because they had a bridge that went straight across.*
> *We didn't get to go on it but we brought that back [Kid Spark bridge lesson].*
> *'What was that (pointing to the beams)? What made it stay that way?'*
> *So that was pretty cool."*
> *– Teacher*

STEM Vocabulary Development

The revised curriculum includes relevant vocabulary for each unit. Some of the vocabulary is related to math learning (e.g., size comparisons, shapes, etc.) and other vocabulary is related to science and engineering (e.g., physics concepts, engineering terms, etc.). Field notes from the observations demonstrated many instances where students used the vocabulary in conversation. Most often students used the vocabulary in conversations with their teachers but there were some instances where students used the vocabulary when talking with each other. Table 4 shows evidence of students' vocabulary use.

Table 4: Evidence of Students' Vocabulary Use

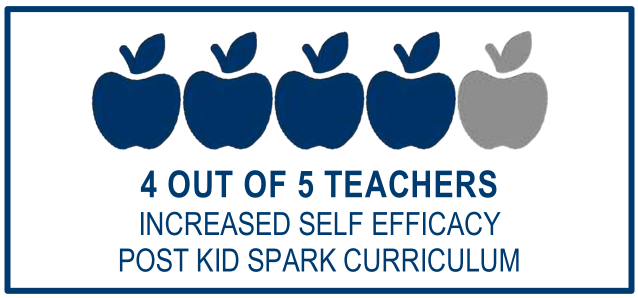
Vocabulary	Field Note Excerpt
Reinforce	TEACHER: We also built a bridge and we made things strong. Do you remember making it strong? BOY: The word was reinforce. TEACHER: Yes.
Gravity	*Teacher holds green block up and lets it go (it falls to floor).* TEACHER: What made it move? GIRL: Gravity.
Arch	GIRL *(to the other kids at her table)*: Look, if I put these two together I can connect them and make an arch.
Joints	TEACHER: What are the places called where the blue ones come together? A FEW KIDS: Joints.
Pyramid	TEACHER: What else did you learn? GIRL: There are six pyramids on top of the green block.
Cube	BOY: If you put two together it is the same as the yellow cube.

Impact on Teacher Learning

One of Kid Spark's primary goals is to increase teachers' self-confidence as STEM educators. Based on classroom observations, results from the Engineering Self Efficacy Teacher Survey, and teacher feedback, teachers' participation in designing and implementing the Kid Spark curriculum improved their self-efficacy as an engineering educator and value for teaching engineering. However, teachers still indicated a need for more knowledge of engineering content and more opportunities to teach engineering to young children.

Self-Efficacy in Teaching Engineering

Teachers' self-efficacy in teaching engineering was low at the start of the year (Mean=2.6 on a 5-point scale) but increased for four out of five of the teachers (Mean=3.1).



The following quotes from the final focus group illustrate both teachers' increased self-efficacy and their continued apprehension about the content area.

"If someone had told me I had to teach engineering, I would have said there's just no way, and I still don't think I was equipped to do that great a job, but I learned that I could get through it, I can do this, it will be okay, and they'll still learn something."

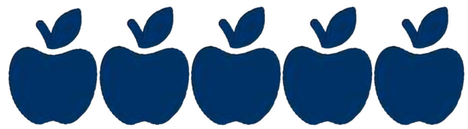
"Certain areas I feel more comfortable in, in terms of the vocabulary being used and more exposure to what engineers do, but I still think I need more practice in the hands-on things because when I look at the picture I can't quite see what's behind. Maybe I need one of those 3-D shots. More practice with that."

"There is always a feeling that I don't know if I'm covering it just right."

"If somebody had told me to teach engineering before I would have said I don't have curriculum, I don't have tools and I don't know what I am going to teach, but I definitely learned that it's not so hard if we have what we need."

"It's not scary anymore."

Value for Teaching Engineering
Teachers reported an increased value for teaching engineering to young children. After participating in Kid Spark, all five teachers felt it was more important to know how to teach engineering to young children. (On a 5-point scale, Pre Mean=2.6; Post Mean=3.8).



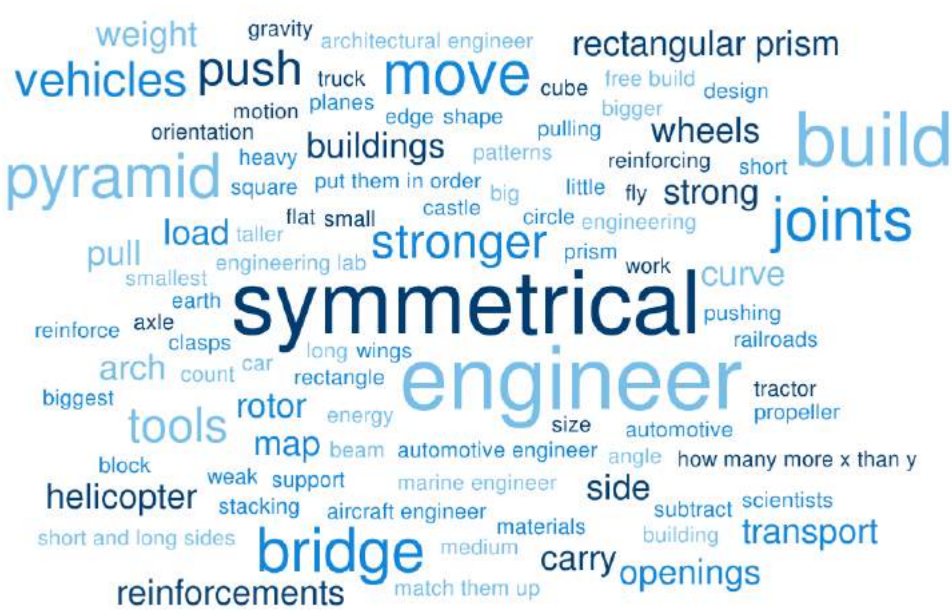
5 OUT OF 5 TEACHERS
VALUED TEACHING ENGINEERING MORE POST KID SPARK CURRICULUM

Infusing Engineering into Instruction

Although teachers expressed a lack of knowledge in engineering as a content area, classroom observations provided clear evidence that using the revised curriculum allowed teachers to introduce STEM vocabulary and engineering concepts through inquiry-based hands-on investigation. The observation protocols were designed to capture each time a teacher used STEM vocabulary during the lessons. Figure 5 depicts the number of vocabulary words teachers were heard using during 17 observations. The size of the word denotes the frequency of its use.

"I learned some terms like 'beam'. I knew that word but applying it to the bridge was new. 'Symmetrical' I used more in second grade but I liked that I could use the blocks to teach symmetry and that I could do this with other cubes too. I liked learning how to test it. Test and reinforce it. I liked that, too. Testing something and making it better."
– Teacher

Figure 5: Teachers' Use of STEM Vocabulary During 17 Kid Spark Lessons (n=5)



In addition to introducing STEM vocabulary, the revised lessons provided teachers opportunities to employ strong pedagogical practices such as asking open-ended questions and using both convergent (single solution) and divergent (multiple solutions) thinking. Although teachers still felt they had a lot to learn in order to become competent engineering educators, they felt their experience with Kid Spark was an important beginning. In fact, all participating teachers enthusiastically reported that they planned to do the curriculum again the following year, and that they felt they would be more prepared to enhance the lessons in the future.

LIMITATIONS

This study was exploratory in nature. The design-based research approach allowed for the enhancement of the PreK-1 curriculum, and the analysis of observational and teacher self-report data suggested that Kid Spark positively impacted students and teachers. However, there were some limitations.

- Although the classroom observations took place in five classrooms with over 100 students, they primarily focused on a single table of four students in one classroom. In future research, it would be important to expand the number of teachers and students included in the focused-observations.
- To truly measure the impact of Kid Spark, we recommend a quasi-experimental research design in which students who participate in Kid Spark are assessed on some key indicators and compared to a group of similar students who do not participate. There are few STEM assessments designed for young children, but the Lens on Science[18] preschool assessment shows promise as a tool for future Kid Spark research.

[18] Greenfield, D. B., & Penfield, R. (2013). Lens on science: development and validation of a computer-administered, adaptive, IRT-based assessment for preschool children. *Institute of Education Sciences Grant* R305A090502, http://ies.ed.gov/funding/grantsearch/details.asp?ID=805

CONCLUSIONS AND RECOMMENDATIONS

The curriculum presented in this study is the result of researchers, teachers, and Kid Spark staff partnering to design a program to meet the needs of young children who do not typically have access to engineering learning experiences. The findings from this report highlight the ways in which the revised PreK-1 curriculum impacted students' and teachers' development of a STEM identity. Students showed evidence of growth in building foundational STEM fluencies, engaging in science and engineering practices, and developing knowledge of the field of engineering. Teachers demonstrated increased self-efficacy and value for the teaching of engineering as well as increased knowledge in basic engineering concepts and practices.

Kid Spark's commitment to the ongoing refinement of their educational programs to best meet the needs of students and teachers is clearly evident in their support of this research study. In light of this commitment to ongoing improvement, adopting the following recommendations will likely lead to a stronger early childhood curriculum that can be adapted to fit a range of educational settings, both formal and informal.

- Utilize the revised curriculum's format and content to guide the final development of the PreK-1 curriculum. In further refinement of the units/lessons, prioritize instruction around the engineering concepts and then align building activities with the concepts.
- Develop training and support materials for teachers that include background information on engineering concepts and practical tips for using the blocks. Teachers preferred a handout for the content knowledge and a video or handout for the construction tips.
- Make minor revisions to the Kid Spark Mobile STEM Labs including re-designing figurines to represent greater gender and ethnic diversity, ensuring there are enough blocks to account for broken blocks and for each child to complete a build from a construction mat, and updating construction mats with high resolution images and step-by-step visual instructions.
- Continue to evaluate both the implementation and effectiveness of Kid Spark's programs. Consider conducting a large-scale evaluation using a quasi-experimental research design, in which there is a comparison group comprised of students and/or teachers who do not participate.

APPENDIX A: METHODS OF ANALYSIS

Qualitative Data Analysis

The qualitative data (field notes and focus groups) were analyzed using content analysis, a method for identifying the themes in textual data. Qualitative data were analyzed using Dedoose qualitative software. All quotes included in the report were edited for readability.

Quantitative Analysis

The quantitative data (coded observations, scored pre/post free build photos, teacher survey) analysis included the following:

- Descriptive statistics to summarize the data (i.e., frequencies, percentages)
- Paired-sample t-tests to test for statistically significant differences between pre- and post-mean (i.e., average) photo scores. For statistical analysis, SPSS statistical software was used.

APPENDIX B: CLASSROOM OBSERVATION CODING RUBRIC

Foundational Fluencies

	NA	No Evidence	Some Evidence	Clear Evidence
Mental Rotation	No opportunity to build	Child does not actively build or model	Child attempts mental rotation, construction resembles what they are trying to make	Child mentally rotates object successfully, construction is an exact replica of what they are modeling
Sequencing	No pre-determined sequence to follow	Child does not follow a pre-determined sequence	Child attempts to follow sequence but misses steps and does not recognize missed steps	Child successfully follows sequence to build
Pattern Thinking	No opportunity to recognize or create a pattern	Patterning not observed	Child recognizes a pattern (verbal or through behavior)	Child creates a pattern
Symmetry	No opportunity to integrate symmetry in the model	Child does not notice symmetry or build anything symmetrical	Child attempts symmetry in construction	Child builds with symmetry and may talk about it

Engineering Thinking

	NA	No Evidence	Some Evidence	Clear Evidence
Gathering information *(K–2-ETS1-1)*	Not an option	Does not ask questions or display any other way of gathering information	Asks questions and/or displays other way of gathering information for what she/he is constructing	Asks questions and gathers information **for the purpose of attaining an expressed goal**
Explaining how things are built/work *(K-2-ETS1-2)*	Not an option	Does not explain what she/he is making or has done.	Explains what she/he is making or has done (verbally, through physical models, sketches, etc.)	Explains what she/he is making or has done, **and how construction works**
Problem solving *(K–2-ETS1-3)*	No problem to solve	Does not rework something to improve function or process	Attempts to rework something to improve function or process (verbal or through behavior)	Reworks something in order to improve function or process
Hypothesis Testing *(K-2-ETS1-3)*	No opportunity to test multiple options	Does not analyze data from tests of alternative designs to compare strengths and weaknesses	Attempts to analyze data from tests of alternative designs to compare strengths and weaknesses	Analyzes data from tests of alternative designs to compare strengths and weaknesses and chooses one that seems to work best

Construction Complexity

Construction Complexity	Lesson 1.1: Big Yellow Block	Lesson 2.2: Pyramid	Lesson 3.1: Bridge	Lesson 3.2: Truck	Lesson 3.3: Castle Wall	Lesson 4.2: Tractor	Lesson 4.3: Helicopter
2+ types of blocks are used	0	0.5	0.5	0.5	0.5	0.5	0.5
Includes a build mat	0	0.5	0	0.5	0.5	0.5	0.5
Includes a predefined sequence	0	0.5	0	0.5	0.5	0.5	0.5
Includes 2 or more blocks with special elements (wheels, risers, etc.)	0	0	0	0.5	0	0.5	0.5
Includes symmetry	0	0.5	0.5	0.5	0.5	0	0.5
Total	**0**	**2**	**1**	**2.5**	**2**	**2**	**2.5**

EXAMPLE CODING SHEET

Date____________________________

Observer__________________________

Teacher Name ________________

Lesson _______________________

Time Period ___________

Child 1 ____________________________

Child 2 ____________________________

Child 3 ____________________________

Child 4 ____________________________

INSTRUCTIONS:

1. Fill in TIME PERIOD manually
2. Observe group for 4-5 minutes, code for 2-3 minutes, but be flexible around time boundaries of different activities

	Child 1				**Child 2**			
	N/A	No (0)	**Some = 1** (Teacher-Prompted?)	**Clear = 2** (Teacher-Prompted?)	N/A	No (0)	**Some = 1** (Teacher-Prompted?)	**Clear = 2** (Teacher-Prompted?)
Mental Rotation								
Sequencing								
Pattern Thinking								
Symmetry								

	Child 3				**Child 4**			
	N/A	No (0)	**Some = 1** (Teacher-Prompted?)	**Clear = 2** (Teacher-Prompted?)	N/A	No (0)	**Some = 1** (Teacher-Prompted?)	**Clear = 2** (Teacher-Prompted?)
Mental Rotation								
Sequencing								
Pattern Thinking								
Symmetry								

APPENDIX C: PHOTO CODING RUBRIC

			Possible Score	Actual Score
Construction Complexity	CC1	2+ blocks attached together	0.5	
	CC2	2+ types of blocks are used	0.5	
	CC3	Model is stable	0.5	
	CC4	Model pieces are mostly connected (e.g., there are few gaps between blocks)	0.5	
	CC5	Model has internal spaces (e.g., tunnels, bridge connecting 2 pieces)	1	
	CC6	Model is 3-dimentional (more than 1 single row of blocks)	1	
	CC7	Model incorporates concepts from previous lessons	1	
Symmetry	S1	Model is at least partially symmetrical	0.5	
	S2	Model is symmetrical	0.5	
Pattern	P1	Model contains a pattern (e.g., more than 2 repetitions)	0.5	
			Total	

APPENDIX D: REVISED CURRICULUM

Unit 1 It's All About the Blocks	Primary Unit Objective: Get excited about using ROK Blocks	Recommended Grades: TK, K, 1st

Developing STEM Identity: This unit is designed to introduce young students to ROK Blocks during short learning experiences. By focusing their attention on each of the four basic ROK Blocks, students will learn the properties and function of each and be better able to use them in their own creative designs, in future lessons, and free play. The lessons are intended to ensure children experience success immediately.

Alignment to STEM Standards: Unit 1 engages students in multiple opportunities to compare and contrast ROK Blocks and the shapes and constructions that can be made with them. Students begin to explore scale and proportions. They are introduced to the idea that the physical structure of objects is related to their functionality. They are asked to make frequent observations. The table below outlines the Student Learning Objectives (SLO) for Unit 1 and their alignment to the Next Generation Science Standards (NGSS) and the Common Core Stand Standards in Math/California Preschool Learning Foundations.

- NGSS Disciplinary Core Ideas (DCI) are standards related to content knowledge.
- NGSS Science and Engineering Practices (SEP) and Cross-Cutting Concepts (CCC) provide a foundation for all scientific and engineering disciplines and are particularly important to develop in young children.
- Common Core Stand Standards in Math and the California Preschool Learning Foundations help teachers integrate ROK Block experiences with math curriculum and to help build a continuum of engineering learning from preschool to the primary grades.

Unit Learning Objectives	NGSS DCI	NGSS SEP	NGSS CCC	CCSS-MA/CA PreK
SLO 1: Become familiar with and use ROK Blocks to build models.		Develop a simple model		
SLO 2: Compare/contrast number, shape, size, color of basic blocks.	Critical thinking: compare/contrast	Using mathematical & computational thinking	CCC-3 Scale, proportion & functionality	Counting objects, comparing sets
SLO 3: Identify and name 2 and 3 dimensional shapes that comprise the basic ROK Blocks.			CCC-6 Structure & Function	Geometry—Identify & describe shapes
SLO 4: Observe blocks closely, identifying details, and functionality.	Making observations	Asking questions based on observations	CCC-6 Structure & Function	Describing the physical world using geometry

Unit 1: It's All About the Blocks

Unit 1 Lesson Overviews

Lesson 1: Big Yellow Block (15 to 20 min)

Introduces the largest ROK Block and fundamental characteristics of basic ROK Blocks, such as pyramids and openings, and how the blocks fit together and come apart. [Note: Lesson 1 & 2 can be combined, if time permits.]

Lesson 2: Little Blue Block (15 to 20 min)

Introduces the Blue block. Helps children compare size and use size vocabulary. Allows children to explore spatially and physically how two blue blocks can combine to equal one yellow block.

Lesson 3: Little Red Block (30 to 40 min)

Students meet the Red block, which has quite a different shape from the Blue and Yellow blocks. Using just the Blue and Red blocks, students explore how they are the same and different, using Red blocks to create a circle and Blue blocks to create a straight line.

Lesson 4: Medium Green Block (20 to 30 min)

Students complete their introduction to the four basic ROK Blocks. They begin using blocks to make their own creations.

Target Vocabulary		
Size	Rectangle	Compare
Big(ger/est)	Line	Same
Large(r/st)	Circle	Different
Small(er/est)	Curve	Symmetry
Medium	Arch	Straight
Long(er/est)	Round	Red
Short(er/est)	Pyramid	Blue
Tall(er/est)	Cube	Yellow
Half	Rectangular Prism	Green
Double	Connect	Edge
Twice	Separate	Side
Square		Medium

Recommended Children's Literature

"*Not a Box*" by Antoinette Portis

"Build It!: Structures, Systems and You" by Adrienne Mason

"Give Me Half!" by Stuart Murphy

"Shapes Are Everywhere!" by Charles Ghigna

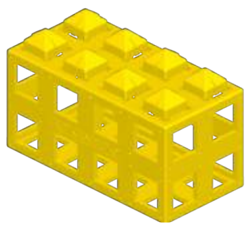
Classroom Organizational Tips

All the lessons in Unit 1 can be taught whole class (with or without older student facilitators) or in teacher-facilitated small groups. The lessons are designed to be implemented with small groups of children seated around a shared table. At times it is helpful to have children work in pairs, sharing their observations with their partner.

Unit 1: Lesson 1 The Big Yellow Block

Key Concepts: We use ROK Blocks to help us learn math and build things. The Big Yellow Block is made up of squares and rectangles.

Materials per Child



2x

Introduction

"Today we're going to start using some special blocks, called ROK Blocks. We use ROK Blocks to learn math and to build things. These special blocks make learning math even more fun.

Today we're going to use the biggest block: The Big Yellow Block. Later [this week, next week] we'll use other blocks too."

CORE Learning Activity

Give every child one Yellow block.

"Everyone look at your block closely. What do you notice?"

Ask children to share what they notice with each other.

Potential prompt questions:

- What does it feel like? [Point out texture on sides, openings, pyramids/ cones]
- Which is a long side?
- How many long sides does it have?
- How many openings does the Yellow block have on a long side?
- Which is the short side?
- How many short sides does it have?
- How many openings does the Yellow block have on a short side?
- Which side is different?
- What shape does the short side look like?
- What shape does the long side look like?

CORE Learning Activity (cont.)

"I think the Yellow block is a shape called a Rectangular Prism. Can you say rectangular? Now say prism. Let's find out if the Yellow block IS a rectangular prism. A rectangular prism has six sides. Let's count them together." [Count the four long and two short sides.] "***A rectangular prism also has 12 edges. What is an edge? Can you touch the edge of your desk?"*** [Demonstrate touching edge of a desk] "***Now, let's see if we can find and count the twelve edges on the Yellow block."*** [Count edges]

[Note: It is okay if students have difficulty counting edges. This activity is designed to introduce them to the parts of 3-D shapes.]

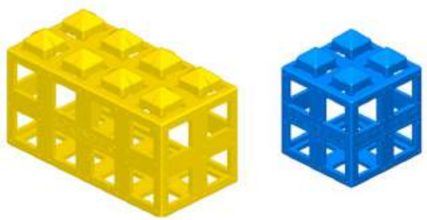
Give students a second Yellow block. Demonstrate and allow students to practice putting the blocks together and taking them apart.

Tip: It is easier to pull blocks apart using a bending or twisting motion instead of pulling them straight out.

Unit 1: Lesson 2 The Little Blue Block

Key Concepts: There are different sizes of ROK Blocks. The Blue block is in the shape of a cube. Two Blue blocks can be put together to be the same size and shape as a big Yellow block.

Materials per Child



Introduction

"Remember [last week; yesterday] when we started using ROK Blocks? We learned about the Yellow block. Today we're going to learn with a different ROK Block, the Blue block."

CORE Learning Activity

Give every child two Blue ROK Blocks.

"Look at your blocks. What do you notice?"

Ask children to share what they notice .

Potential prompt questions:

- How many sides does it have? Let's count the sides. (6)
- How many openings does the Blue block have on each side? (4) How many altogether? (24)
- Which side is different? (pyramid side)
- What makes it different? (pyramids)
- How many pyramids are there? (4)
- What are the pyramids for? (attaching to other blocks)

"Notice that all the sides are the same size on the Blue block. When a shape has six square sides that are all the same size, it is called a cube."

Demonstrate and encourage students to practice putting the blocks together and taking them apart.

"The Blue ROK Blocks go together the same way the Yellow ROK Blocks go together."

Give each student a Yellow ROK Block.

"Do you remember what kind of shape the Yellow block is? It is a rectangular prism.

What do you notice about the size of the Blue block compared to the size of the Yellow block?"

Use the words "half", "double" and "twice as large" to compare the sizes of the Blue and Yellow blocks.

Demonstrate how the Blue ROK Blocks can fit together with the Yellow ROK Blocks.

CORE Learning Activity (cont.)

(**TIP:** it is easier to attach blue blocks to the bottom rather than the top of the Yellow block)

"What do you notice about the way the Blue blocks and the Yellow blocks fit together?"

Potential prompt questions:

- How can you put the Yellow and Blue blocks together to make a long shape? [Demonstrate how to attach the Blue blocks to the square end of the Yellow block.]
- How can you put the Yellow and Blue blocks together to make a square shape? [Demonstrate how to attach the Blue blocks to the Yellow block to form a square.]

"How are the Blue blocks the same as the Yellow blocks? How are they different?"

Learning Extensions

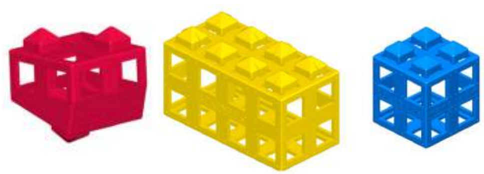
Ask students to put a Blue block and a Yellow block next to each other on their desks and then stand up behind their chairs. Have students look closely at the Yellow block and then close their eyes.

Ask them to imagine they are inside a Yellow block that's big enough for them to stand in. Ask them to reach up to feel the top of the block, then the sides, and then the bottom. Repeat this activity with the Blue block. Then ask students how the Blue and Yellow blocks are the same and different. Ask which is bigger.

Unit 1: Lesson 3 The Little Red Block

Key Concepts: ROK Blocks include Red blocks that can be used to make curves/arches.
Red blocks can be put together two different ways. Putting lots of Red blocks together facing the same direction makes a circle.

Materials per Child



6x 1x 1x

Introduction

"Today we're going to use a ROK Block that is very different from the blocks we've used so far. I'm wondering if you can figure out what is different about it."

CORE Learning Activity

Give every child one Red ROK Block.

"Look at your blocks. What do you notice about this block that is different than the other blocks?"

Potential prompt questions:

- How are the sides different from the other blocks? (Two sides are angled. There are pyramids on two sides, instead of just one side.)
- How many pyramids are there on the sides with pyramids? (2) How is this different from the other blocks? (On the Blue/Yellow blocks, the sides with pyramids have only pyramids, and not openings.)
- Why do you think this block is shaped this way? (Encourage students to really think about this question. The answer: to make curves/arches/circles.)

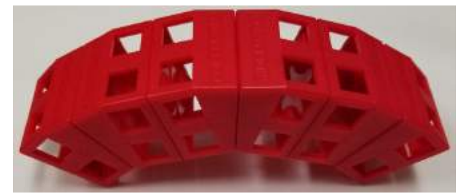
Give the students a 2nd Red block. Ask them to explore the different ways that the two blocks can be put together.

Now tell them to connect the two blocks so that the letters (the logo) are next to each other on top. The bottom of the two blocks should form a "V".

Have the students repeat the process with the other pairs of Red blocks.

CORE Learning Activity (cont.)

Now demonstrate that if you put pairs together, it forms an arch. Review what an arch is. Have the students connect the pairs together to form an arch. **Note: The correct way to do that would be so that all the letters (logos) are visible on top and there are no letters (logos) underneath the arch.**



Ask the children to predict what they think the shape will look like if they keep adding to the arch. After the students predict a circle, have them pair up with another student and connect their chain of blocks to form a bigger chain. Then have each table connect all their blocks together. The circle will be complete when they join 24 blocks.

Learning Extensions

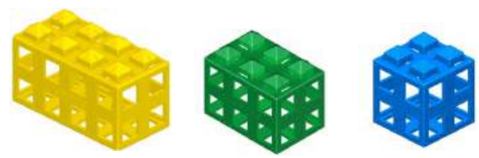
Have students go on a scavenger hunt through their classroom (or playground, library, cafeteria) to find shapes that are similar to the circle made with Red blocks. Have children report out to the class what they found.

Unit 1: Lesson 4 The Medium Green Block

Key Concepts: ROK Blocks include a medium Green Block. It is bigger than the Blue block and smaller than the Yellow block.

Materials per Child

For Part 1:



1x   1x   2x

For Part 2:

All basic blocks

Introduction

"So far we've used three basic ROK Blocks. There is one more basic ROK Block. It is the Medium Green block. Let's compare the Medium Green block with the Big Yellow block and the Small Blue block."

CORE Learning Activity

Part 1:

"Hold up the SMALLEST ROK Block! "
[For each, hold up the correct block after the majority of children have responded.]
"How many pyramids does it have? Show me with your fingers what your guess is." *(4)*

"Let me see the BIGGEST ROK Block! How many pyramids does this block have?" *(8)*

"Now show me the MEDIUM-sized ROK Block! And how many pyramids does this block have?" *(6)*

"Let's put the blocks together to make some steps."

Demonstrate how to build this structure.

Potential prompt questions:

- How many more pyramids does the Yellow block have than the Green block?
- How many more pyramids does the Green block have than the Blue block?
- How many more pyramids does the Yellow block have than the Blue block? [You can have the kids connect Yellow and Blue blocks to check their answers.]

CORE Learning Activity (cont.)

Part 2:

As an introduction to the concept of "free build" put all the basic blocks (Yellow, Green, Blue and Red) on the tables.

"Take your blocks apart and put them back together to build anything you would like with all the blocks!"

[Observe the children to ensure they know how to put together and pull apart the blocks. Assist as needed.]

Unit 2 I Am an Engineer!	Primary Unit Objective: Introduce what it means to be an engineer	Recommended Grades: TK, K, 1st

Developing STEM Identity: Some young children grow up knowing an engineer. Most do not. Or, the engineers they know are different from them in gender, race, or other demographic characteristics. This unit extends children's developing skill with using Rokenbok and introduces them to the idea that everyone uses engineering every day. So, they (and their teachers) are already engineers.

Alignment to STEM Standards and Math Learning Progressions: Unit 2 builds on skills and capacities introduced in Unit 1, with a focus on problem-solving, patterns, visual-spatial reasoning, and symmetry.

Unit Student Learning Objectives (SLO)	NGSS DCI	NGSS SEP	NGSS CCC	CCSS-MA/CA PreK/Math Learning Progressions
SLO 1: Manipulate ROK Blocks to build increasingly complicated structures.	ETSI.B: Developing possible solutions	SEP-2 Developing & using models	CCC-6 Structure & Function	Combine different shapes to make an object or design
SLO 2: Explore what engineering is and what engineers do.	ETSI1.A: Defining/ engineering problems	SEP-1 Asking questions & defining problems		Reason abstractly & quantitatively Describe & compare measurable attributes Quantitatively compare 2 or more groups
SLO 3: Compare and contrast size and shape of blocks.		SEP-6 Designing solutions	CCC-3 Scale, proportion & functionality	
SLO 4: Match 3-dimensional objects to 2-dimensional pictures.				Recognize 3D objects in 2D pictures
SLO 5: Create and analyze patterns.		SEP-4 Analyzing & interpreting data	CCC-1 Patterns	Expand understanding of simple & repeating patterns
SLO 6: Recognize symmetry.			CCC-1 Patterns	Begin to use relational language of right and left

Unit 2: I Am an Engineer

Unit 2 Lesson Overviews

Lesson 1: What is an engineer? (30 to 40 min)

Children explore what it means to be an engineer and then create a tool to use to solve a problem.

Lesson 2: Patterns & Pyramids (30 to 40 min)

In the process of building a pyramid, children explore patterns and symmetry.

Lesson 3: What's in the box? (30 to 40 min)

Students explore the contents of the ROK Blocks kit and are introduced to the names of each of the pieces and their functions. Children learn how to put together and take apart smaller Rokenbok pieces and see how they fit together with ROK Blocks.

Lesson 4: Free Build (30 to 40 min)

In this free build experience, children are offered the opportunity to freely explore Rokenbok, to create something of their own choosing, and, if they wish and time permits, share their creation with others.

Target Vocabulary

Build	Persistence	Inventory
Engineer	Problem	
Equivalent	Pyramid	
Design	Right	
Left	Solve	
Inventory	Symmetry	
Make	Symmetrical	
Measure	Tool	
Pattern	Vehicle	

Recommended Children's Literature

"What Do You Do With A Problem?" by Kobi Yamada and Mae Besom

"Is it Symmetrical?" by Nancy Allen

"Otto and the New Girl" by Nan Walker and Amy Wummer

"Seeing Symmetry" by Loreen Leedy

"What is Symmetry in Nature" by Bobbie Kalman

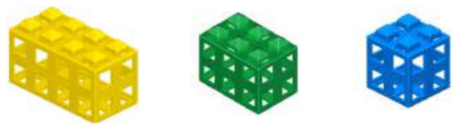
Classroom Organizational Tips

All the lessons in Unit 2 can be taught to the whole class (with or without older student facilitators) or in teacher-facilitated small groups. The lessons are designed to be implemented with small groups of children seated around a shared table. At times it is helpful to have children work in pairs, sharing their observations with their partner. When children use a ROK Block kit, there should be no more than 4-6 children using each kit.

Unit 2: Lesson 1 What is an engineer?

Key Concepts: Engineers are people who design and create things that solve problems. We all solve problems every day, and we often design and create things to solve those problems.

Materials



All the Yellow, Green and Blue blocks from 1 Rokenbok Mobile STEM lab per table

Also, a prepared "measuring tool" made with enough Blue blocks stacked together to be able to measure the shortest dimension of the top of your desk.

Introduction

"You all know that I am a teacher, but did you know that I'm also an engineer? And you are too! Today we're going to learn what it means to be an engineer." Ask children to tell you what the word "problem" means.

"A problem is something that you need to figure out. Sometimes problems can be frustrating or keep us from doing something we want to do. But mostly problems are like puzzles that we need to figure out. Tools can help us solve these puzzles. Engineers are people who solve problems. They often design or make things to help them solve the problem."

CORE Learning Activity

"I'd like you to help me solve a problem today. I'm thinking about rearranging our room, but I have a problem. I don't know how big a lot of things are in our room. I'd like you to help me create measuring tools so we can measure things in the room. That's what engineers do. They make things that help to solve problems. Let's think like an engineer."

Hold up your Blue block measuring tool. Explain why you made your measuring tool the way you did.

"Here is my measuring tool. I made it straight because most of what I want to measure is straight. I made it long because I want to measure long things, but not too long because it might fall apart."

Demonstrate measuring your desk or a student desk using your tool. For the unit of measure, count each block. So, your desk will be X number of a Blue blocks wide and X number of Blue blocks long.

"Now it's your turn. Everyone is going to make a tool to measure things in our classroom. Make a straight tool, because we're going to measure lots of straight things. You can use any color you want, but make your tool from one color of blocks. Before you begin, let's think about what your measuring tool will look like."

CORE Learning Activity (cont.)

Discuss ideas for different ways to create a measuring tool.

Potential prompts:

- What will your measuring tool look like?
- Will it be long or short?
- Will it be wide or skinny?
- Will it roll around or lie flat?
- What shape will you choose? Why?

Prompt students to work together to make sticks at least 10 blocks long. As they finish making their measuring tools, ask them to measure their desks, and any other large object in the room (white boards, cabinets, tables, chairs). Students can also take turns measuring body parts such as arms or legs and comparing to a partner.

Wrap up: "***Tomorrow (next time/next week) we're going to learn more about what engineers do and some ideas they use to design things and solve problems."***

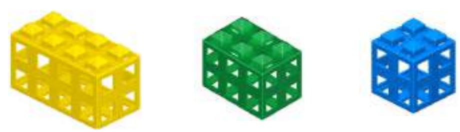
Learning Extensions

- Compare the size of classroom objects. Define what is "big" and what is "small."
- Have students record the measurements they take of various objects in the classroom on the board

Unit 2: Lesson 2   Patterns & Pyramids

Key Concepts: Engineers build things in different ways depending on what the thing needs to do and what problem it is helping to solve. Engineers pay attention to things like pattern and structure**.**

Materials per 2 Children



4x **6x** **12x**

Also, one Pyramid Construction Mat for each pair.

CORE Learning Activity

"***Remember [last week; yesterday] when we started to learn about what engineers do? Well, today we're going to learn more about how to think like an engineer*****.** ***Engineers love patterns. Patterns are things that repeat. We can make a pattern with clapping."***

[Clap a simple pattern like slow, fast-fast, slow, fast-fast. Have the children repeat after you. Then change the pattern, like slow, slow, fast-fast-fast, slow, slow, fast-fast-fast.]

"Patterns are all around us." [Depending on your students' familiarity with patterns either ask them to point out patterns or point out a few yourself (like patterns on the walls, ceilings, etc.)]

CORE Learning Activity (cont.)

"We can make patterns with ROK Bloks. Everyone take 2 blue, 2 green, and 2 yellow blocks. Let's make a repeating pattern." Place the blocks on a table in front of you, pyramid side up, and, without connecting them, make a pattern: Blue, Green, Yellow; Blue, Green, Yellow. As you place the blocks say: ***"I'm putting the blocks down in this sequence: Blue, Green, Yellow. A sequence tells us the order of a pattern. It tells us what comes first, and second, and next."***

Ask children to copy your pattern, and then ask them to share what they notice about the pattern. Potential prompt questions:

- What else do you notice about this sequence? (It goes small, medium, large. Four pyramids, 6 pyramids, 8 pyramids)
- Can you make a different pattern with these 6 blocks (Such as B, B, G, G, Y, Y). Ask children to talk you through their pattern.

Ask children to put aside, for now, all but 1 Blue, 1 Green and 1 Yellow block. Ask them to work in pairs.

"Now, let's build a pyramid." Ask the children to build the pyramid using steps from Unit 1.

Pass out the Pyramid Construction Mat. Show them how they have built the first part of Step 1. Demonstrate how to add the next layer (Green block and Blue block). Demonstrate the next two layers as they build, providing support as needed.

"Okay. Now you have half of the pyramid built. Let's build the other half, but this time, we will only use Blue and Green blocks."

CORE Learning Activity (cont.)

Demonstrate and provide support as needed. When both sides are built, stand them next to each other, tall sides together.

"What do you notice about the two sides of the pyramid?"

Potential prompt questions:

- How are the sides the same? (Same size/shape) How are they different? (Different block colors, different number of blocks)
- How is it possible that the two sides are the same size but use a different number of blocks? (Yellow blocks are twice as big as Blue blocks.)
- "Walk" your fingers up the angled side of the pyramid and ask students what it reminds them of. (Stairs)

"Engineers use lots of different patterns to solve problems and create things in our world. Sometimes patterns are symmetrical." Demonstrate symmetry with any blocks.

"The left side is the same as the right side, just in a different orientation. Orientation means the shape is turned a different way."

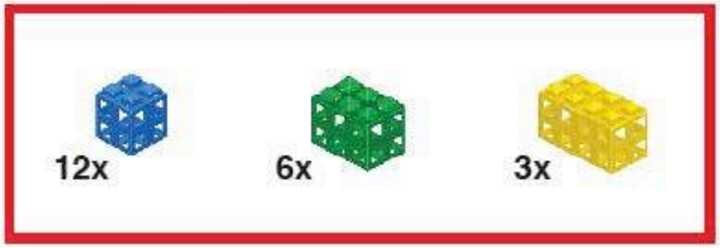
"But if both the left side and right side are turned the same way, they are exactly the same size and shape. That is called symmetry.

Now, let's make a pattern with our pyramids."

Have the students place their pyramids next to each other in a long row with tall sides next to each other and short sides next to each other. Point out where the pattern is symmetrical.

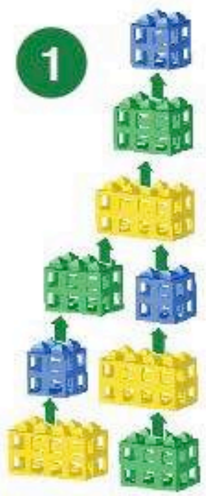
PYRAMID

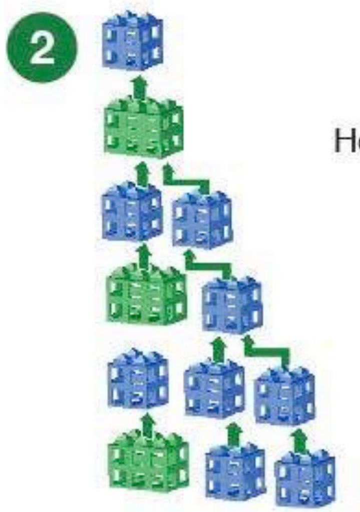
BILL OF MATERIALS



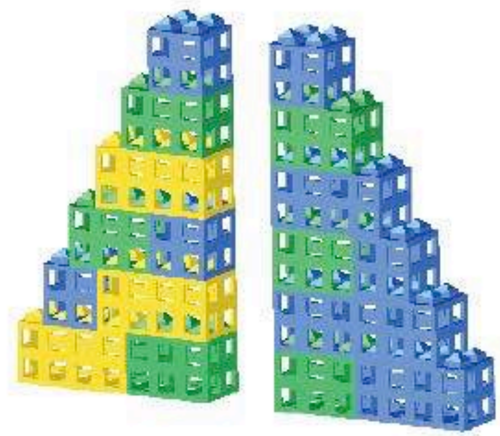
COUNTING & COMPARING

- Count the blocks in the left half pyramid and the right half. Which has more blocks?
- How many blocks tall is the pyramid?
- How many blue, yellow, and green blocks do you have? How many blocks total?





How many **blue** blocks equal one **yellow** block?



Common Core K.CC.C.6

Unit 2: Lesson 3 What's In The Box?

Key Concepts: Engineers make sure they know what tools and resources they have to work with. ROK Blocks has lots of pieces beyond the basic blocks that can be used to design and build interesting and useful things!

Materials Per Student Group

1x

1x

Pre-lesson prep:

This lesson introduces the smaller Rokenbok blocks and specialty pieces to the children. The smaller blocks can be more difficult for little hands to push together and pull apart. They are easier to pull apart if you pull at an angle, rather than trying to pull them straight out. The smaller pieces snap together in two different ways.

Refer to the "Get to know your blocks" section of the Instructor's Guide to make sure you are familiar with and can demonstrate how to use the smaller pieces.

Introduction

"So far we've used just the 'basic' ROK Blocks, but there are a lot more blocks in the box that we can use to build fun and useful things. Engineers always want to know what tools and materials they have to work with, so today we're going to see what is in the ROK Blocks box."

CORE Learning Activity

Give each group of students a ROK Blocks Lab and a Matching Game Mat. With your own set of blocks, hold up a block from the Matching Game Mat and have children locate it on the mat. Do this with each block on the mat. Next, have each group of students locate the blocks and place them on the Matching Game Mat.

Once you've completed the matching game, explore how several of the specialty blocks work. Start by showing the children that the smaller blocks snap together differently than the basic ROK Blocks.

"Everyone get a Riser and a Yellow block. The Riser is light gray and is two squares long. The smaller pieces are special because they can fit together with other Rokenbok blocks in three ways." [Hold up the Riser so the connectors are at the top.] "***See those two fingers at the top? They can snap into the openings on the Yellow block in two ways. Watch me while I show you."***

CORE Learning Activity (cont.)

Demonstrate how to snap the Riser into the openings of the Yellow block and how to snap across the "bridge" points (the solid part between the openings). Demonstrate that it is easier if you snap and unsnap the pieces by prying them at an angle, rather than pushing/pulling straight in and out. If some children have difficulty, assist them and assure them with practice they'll be able to snap and unsnap them.

Next demonstrate how the Riser fits on the pyramids. Allow children to fit the Riser on the pyramids.

Explore other specialty pieces as time allows. Potential prompt questions:

- Which piece would you use for wheels on a vehicle? (wheels)
- What do you think you could use the "hinge" piece for?

Learning Extensions

Play *Can You Find Me* to help children learn to recognize, name, and know the function of each piece. For each of the following variations, ask children to find the matching piece: Hold up a piece; Point to a piece on the inventory sheet; Name a piece; Name a function (what piece makes two other pieces swing? - hinge).

Unit 2: Lesson 4 Free Build

Key Concepts: We can use our new skills and ROK Blocks to design and build things. Engineers make their creations and then improve on them.

Materials Per Student Group

1x

Introduction

"So far I've given you ideas about what to build and how to use ROK Blocks to make things.

But the best thing about ROK Blocks is getting to think up something ourselves and then figure out how to build it."

CORE Learning Activity

Have children work in groups of four or five, sharing one ROK Block Lab. Provide the list of ROK Block Parts and inventory mats, which the children may or may not find useful.

You may wish to start the free build lesson with establishing classroom norms for sharing and working with the blocks. One important "rule" to establish is that there are no "mistakes" when building with ROK Blocks. There are only "improvements" and "do-overs."

You may choose to circulate among the students or build your own creation, or both. As you interact with students ask them to tell you about their creation.

Potential prompt questions:

- What are you making?
- What do you want your object to do?
- Can you show me with your hands what you're trying to make?
- Where are the patterns in what you're making?
- How tall will it be?
- How many [color] blocks do you think you'll need to make it that tall?
- What could you do to make it roll?
- What could you do to make it stronger?

If you build your own object, it is helpful for you to "think aloud" about what you're doing, and

CORE Learning Activity (cont.)

to especially comment when you decide to revise your design.

Potential Think Aloud comments:

- Oh, I need a lot more Blue blocks than I thought I would need.
- These smaller pieces are harder to put together than the ROK Blocks, but I practiced and now I can twist them apart just fine.
- I thought the Yellow blocks would be the best choice, but they are too big. I see that the Green blocks would work better because...

Learning Extensions

Free build time offers a great opportunity to connect children's Rokenbok experience with other subjects and skills. If time permits, you can extend children's learning before they build by having them draw or describe what they intend to build. Also, children can strengthen speaking skills by giving "show and tell" presentations about their creations to their classmates. They can practice writing skills by taking a picture or drawing their build in their class journals and writing or dictating a few sentences about it. Children can connect to their environment or community by identifying similar objects in their home, school or neighborhood.

Unit 3 Engineers Make Things Strong	Primary Unit Objective Introduce children to one of the primary tasks of engineering: making things strong	Recommended Grades TK, K, 1st

Developing STEM Identity: In this unit, children expand on their growing understanding of engineering and what it means to be an engineer. The activities engage them with a real-life problem that often faces engineers: how to make things stronger. The children also learn part of the design cycle by testing their designs and improving them.

Alignment to STEM Standards and Math Learning Progressions: Unit 3 focuses on a specific engineering problem—making things stronger—and explores different ways to improve strength. The unit also expands children's skills using ROK Blocks by introducing the use of a wheel.

Unit Student Learning Objectives (SLO)	NGSS DCI	NGSS SEP	NGSS CCC	CCSS-MA/CA PreK/Math Learning Progressions
SLO 1: Manipulate ROK Blocks to build increasingly complicated structures	ETSI.B: Developing possible solutions	SEP-2 Developing & using models	CCC-6 Structure & function	Combine different shapes to make an object or design
SLO 2: Explore a specific problem engineers often face (how to make things stronger)	ETSI1.A: Defining/ engineering problems	SEP-1 Asking questions & defining problems	CCC-6 Structure & function	
SLO 3: Understand that pushes on objects can have different strengths and that bigger pushes cause bigger changes in the object	PS52.B/PS53.C Pushes/pulls on objects can have different strength; bigger pushes/pulls cause bigger changes	SEP-6 Designing solutions	CCC-3 Scale, proportion & functionality CCC-2 Cause & effect	
SLO 4: Match 3-dimensional objects to 2-dimensional pictures				Recognize 3D objects in 2D pictures
SLO 5: Test constructions for strength; Try to improve strength by using different designs		SEP-3 Planning and carrying out investigations	CCC-3 Scale, proportion & functionality	
SLO 6: Recognize symmetry			CCC-1 Patterns	Begin to use relational language of right and left

Unit 3: Make Things Strong

Unit 3 Lesson Overviews

Lesson 1: How much load can it hold?

(20 to 30 min)

Children explore what it means for something to be strong and the relationship between weight, strength, load and reinforcement.

Lesson 2: The Long Haul (20 to 30 min)

Children apply what they have learned about making thing stronger to building a flatbed truck. They also learn that wheels help make work easier.

Lesson 3: Make Your Castle Strong

(20 to 30 min)

Children use their new engineering skills to build and test a castle wall, and then improve on the design to make it stronger. Extended activities can move children into a "focused" free build, where children can create their own castle wall designs and test them for strength.

Lesson 4: Free Build (30 to 40 min)

In this third "free build" experience, children freely explore Rokenbok and are encouraged to create something of their own choosing and also to make it strong.

Target Vocabulary

Beam	Push
Bridge	Reinforce
Energy	Reinforcement
Force	Strong(er)
Joint	Test
Load	Vehicle
Machine	Work
Pull	

Recommended Children's Literature

"Building Bridges" (Young Engineers) by Tammy Enz

"Go! Go! Go! Stop!" by Charise Mericle Harper

Classroom Organizational Tips

All the lessons in Unit 3 can be taught to the whole class (with or without older student facilitators) or in teacher-facilitated small groups. The lessons are designed to be implemented with small groups of children seated around a shared table. At times it is helpful to have children work in pairs and share their observations with their partner. When children use a Rokenbok Mobile STEM lab, there should be no more than four children using each lab.

Unit 3: Lesson 1 How Much Load Can it Hold?

Key Concepts: One of the most common problems engineers solve is how to make things stronger. Adding reinforcements that can help distribute the weight or load is one way engineers make things strong.

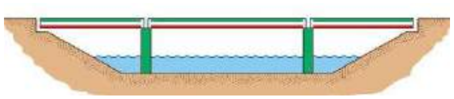
Materials per 2 Students

- Ten Blue blocks
- Several Yellow and Green blocks
- Ten Blue blocks and one Yellow block for the teacher's demonstration bridge

Introduction

Engage the children in a discussion about bridges. Ask children to raise their hands if they have driven, ridden or walked over a bridge lately. If there are bridges in the local neighborhood, ask if any of the children live near them, or cross them frequently. Ask them what bridges do and why we need them.

"Today we're going to build bridges. We're going to build the most common type of bridge. It's called a <u>beam bridge</u>." Draw a simple beam bridge on the whiteboard/chalkboard or paper. "***The long part in the middle is called a beam."***



CORE Learning Activity

Demonstrate how to build the bridge by connecting 8 of the 10 blue blocks, forming a long beam. Then, use one blue block to form a pedestal at each end of the beam.

As children finish building their bridge ask: "***What do you notice about our bridges? "***

Potential prompts:

- Are they symmetrical? Are they long and thin, or short and wide? What do you notice about the middle of the bridge?

"Let's <u>test</u> our bridges to see how strong our bridges are. Put your bridge on the table. "Testing" means we're trying out the <u>bridge</u> to see if it works. Think about the question I'm going to ask you: What do you predict will happen if you walked on it?" (It would break.)

"What do you predict would happen if you were to just lean on it?" [After making their predictions, have children put their bridges on their desks or on the floor and lean on their bridges. Make sure every child has the chance to lean on a bridge and break it. Feeling their own body's force against the bridge helps them understand the relationship between load and strength.]

"When we lean on our <u>bridges</u>, we're putting our

CORE Learning Activity (cont.)

weight on it. Weight on a bridge is called a "<u>load</u>." When have you heard the word "<u>load</u>" before?" (A load of laundry, picking up a load of garden soil, etc.)

"Our bridges are not strong enough for us to lean on them. How could we make them stronger?" (Make the beam shorter, make them "thicker.")

Provide the children with other ROK Blocks and let them experiment.

After they have tested various configurations by leaning on their bridges, add a yellow block to the middle of your bridge. Say:

"I <u>reinforced</u> my <u>bridge</u> by putting a yellow block under it. The word <u>reinforce</u> means to strengthen something. We can <u>reinforce</u> our Rokenbok creations by adding blocks. Some places are better than others for <u>reinforcement</u>. I put the block across the <u>joint</u> where two blue blocks come together and it is often the place where a <u>bridge</u> is weak. A joint is where two blocks are joined. Next time we work with ROK Blocks we will build something designed to move heavy things."

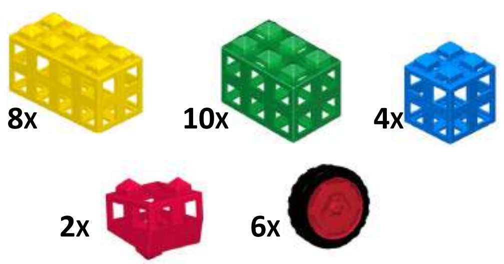
Learning Extensions

Have children work in groups to test their bridges to see which are the strongest. They can lean on bridges or put heavy objects such as books on the bridges to see which designs can bear the heaviest loads.

Unit 3: Lesson 2   The Long Haul

Key Concepts: Designing ways to move heavy things is something many engineers do. Engineers define work as the energy it takes to make something move, change direction or stop moving.

Materials per 2 Students



- Basic Truck Construction Mat

CORE Learning Activity

"***Remember [last week; yesterday] we learned about making a bridge strong? Well, engineers design a lot of different things to be strong. Today we're going to learn how to make a truck strong, but first, please tell me what you think of when you hear the word 'work.'"***

Potential prompts or discussion ideas:

- Do you hear your parents or neighbors or brothers/sisters talk about going to work? What does that mean?
- Do you do work here at school?

"Engineers and scientists have a special way they

CORE Learning Activity (cont.)

think about work. Work is the amount of energy it takes to make something move, change directions or stop moving." [Engage the children in a discussion of how they do this: running, riding a bike, skates/skateboard.]

"When you or your parents need to move something heavy, what do you use to move it?" (Use a shopping cart, wheel barrow, truck/car, hand truck/dolly.)

"What do a shopping cart, car, and wheel barrow all have that makes it easier to move something heavy?" (They all have wheels.) ***"Wheels make work easier. They make it easier to move something heavy.*** * ***Today we will build a truck."***

Demonstrates steps 1 and 2 to the class drawing special attention to the direction of the pyramids in Step 1 as well as green blocks' alignment in Step 2.

Give out one Basic Truck Construction Mat per 2 students. Then have students builds these steps on their own working in pairs and check for any mistakes (because some of the mistakes in these first steps do not manifest until later steps when they become too complex to correct).

"Let's look at what we've built so far. What do you notice about the truck?"

Potential prompts:

- Is it symmetrical? (Side to side, yes; Front to back, no) How do you know?
- Does the bed of the truck (point to bed) have any reinforcement? (No)

CORE Learning Activity (cont.)

"This truck is supposed to make work easier by moving heavy things. Let's pretend what we've built so far is the way our truck was designed. Now, let's test it the way we tested our bridges. Put your truck on the table and lean on the middle, between the wheels. What happens?" (It breaks.)

"Look at the picture on the construction mat. How is the truck reinforced to make it stronger?" (Layer of blocks on top of the bed. And the wheels are clipped on at joints.)

Invite children to finish building their trucks and then test their strength again.

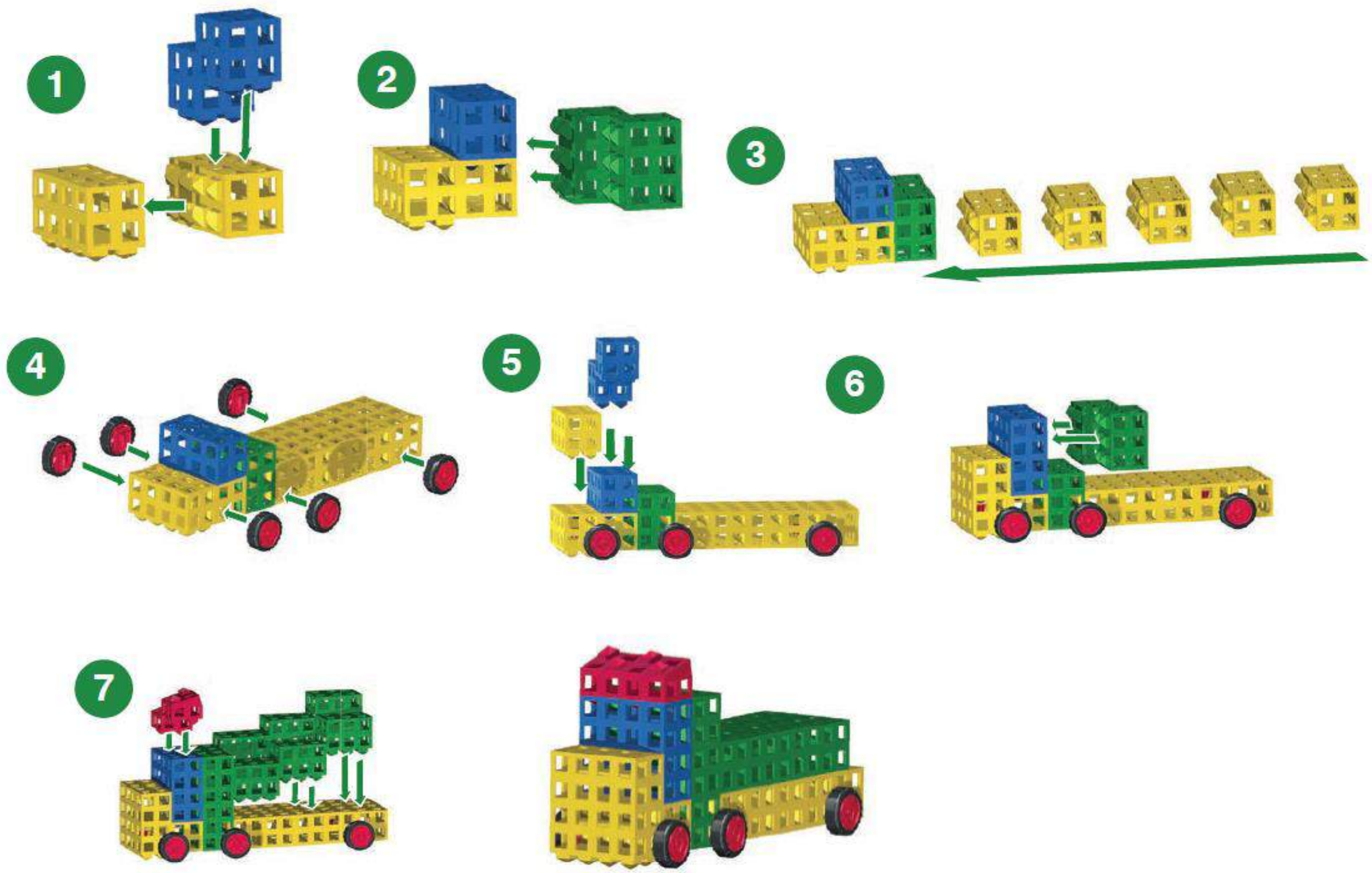
Have children put small objects on their trucks and move them around their desks or the floor. Point out that when the truck is moving objects it is doing work, and that when they make their truck move, they are doing "work" too.

"Today we learned that engineers have a special meaning for the word "work" - to an engineer, work means the energy it takes to move something, change directions, or stop something that is moving."

————

*If children ask or if you are doing an extended lesson on simple machines, you may wish to say, "Wheels make work easier because they reduce friction."

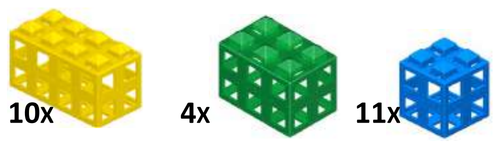
Unit 3, Lesson 2: The Long Haul



Unit 3: Lesson 3   Make Your Castle Strong

Key Concepts: Engineers not only design bridges and trucks, they design buildings. Buildings need to be strong enough to hold up their own weight because they are heavy, and strong enough not to be knocked down.

Materials per Table



- 2 Modified Castle Wall Construction Mats
- Several other blocks for experimenting
- One ram for the teacher (see construction mat)

Introduction

"Engineers design machines, vehicles, tools, furniture—you name it! If we use it, an engineer designed it. Engineers also design buildings. We're in a building right now. Some engineers specialize in designing schools. Others design houses or shopping malls or restaurants."

CORE Learning Activity

"Buildings need to be strong to hold themselves up because they are heavy. Buildings also need to be strong so they don't fall down in a storm or an earthquake.

Today we're going to build part of a building and try to knock it down."

Give each group of four students two Castle Wall Construction Mats. One child will make the left side of the wall, and the other one will make the right side of the wall. Then instruct the children to put their walls together and raise their hand if they are ready for the teacher to test their wall's strength with the ram.

Once the wall is built, roll the ram into the "gate" (Green blocks). Use the word "test" and remind students of what it means to test something. The ram will easily push through.

"Now that we've tested our castle walls, let's think about what we can do to make them stronger. What could we do to reinforce the castle walls?"

In their groups, have children decide on a way to make the wall stronger and raise their hand when they are ready to have their walls tested again. Allow them to try several designs.

Students can either test their castle walls in their small groups, or come together as a class

CORE Learning Activity (cont.)

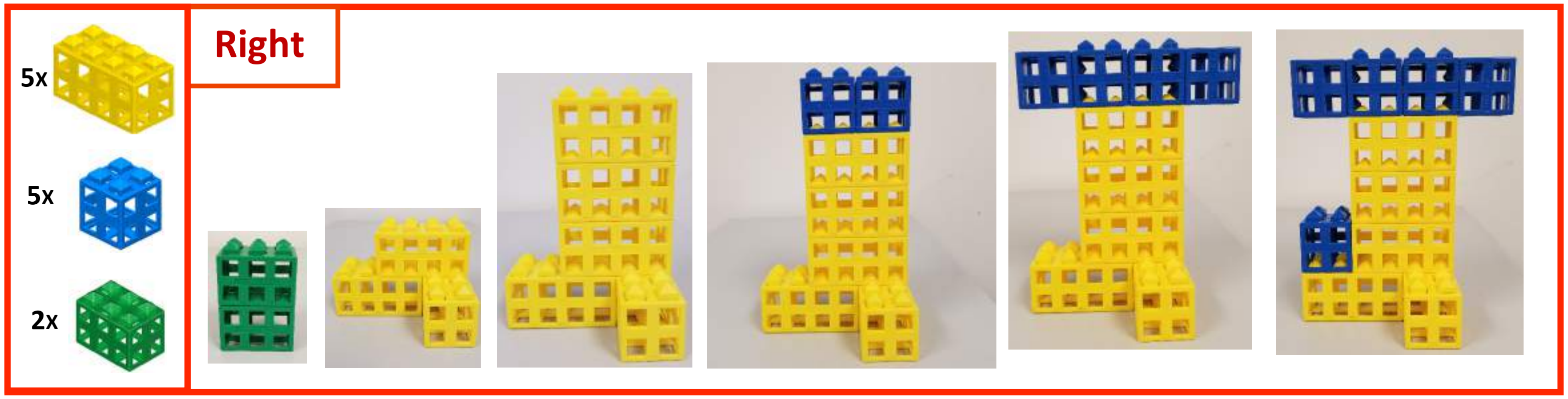
so everyone sees all the designs. You can discuss in a large group the main principles for reinforcement [finding the weak spots first, then reinforcing the weak spots instead of just adding blocks to make the wall taller or wider, etc.]

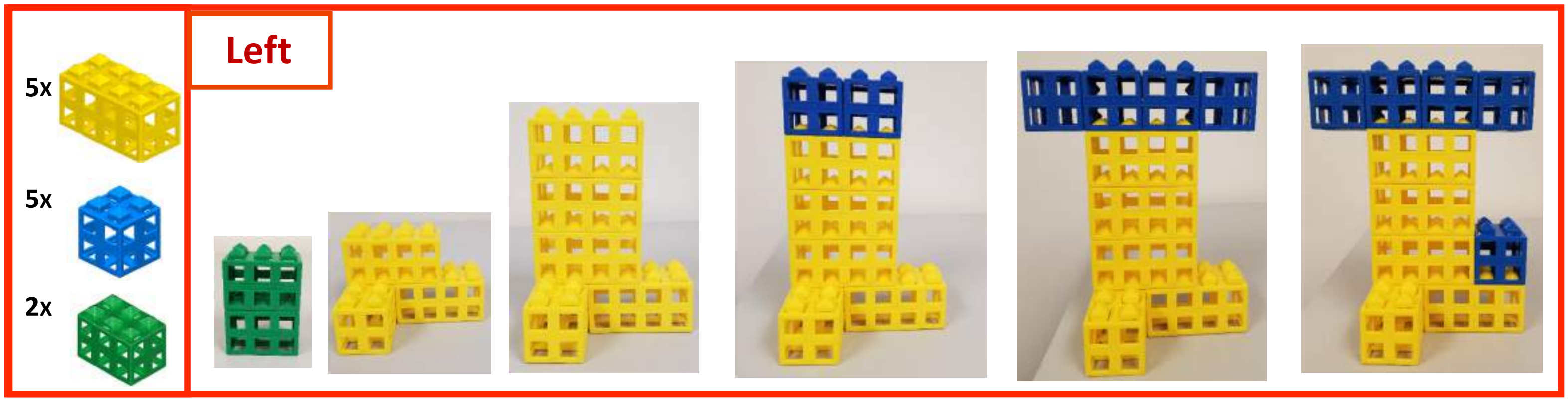
Learning Extensions

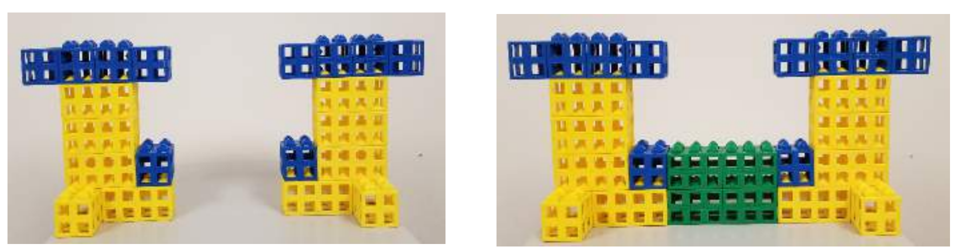
When students test their designs, have them first explain how they improved their design and why they think the improvement is a better/stronger design.

Students can also extend this activity by building other walls or buildings and testing their strength with the ram or by placing the building on a cardboard box or moveable table or cart, and shaking/moving it to simulate an earthquake. Students then improve their designs and test their improvements. Students can also improve the design of the ram to see if it can knock open the improved building designs.

UNIT 3, LESSON 3, CASTLE WALL







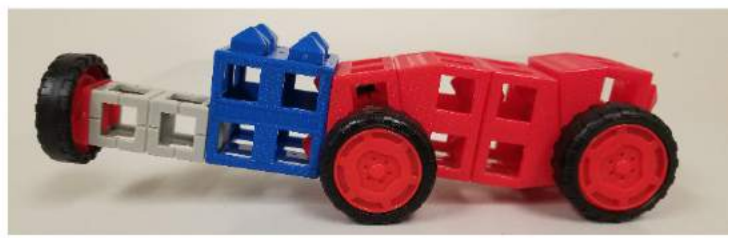
The Ram

Materials:

4x 
1x 
5x 
1x 

1

2



Unit 3: Lesson 4   Free Build

Key Concepts: We can use our new skills and ROK Blocks to design and build things that are strong and that make work easier.

Materials per Group of Students

- Inventory Mats and Bill of Materials

Introduction

"Last week [yesterday, last month] we spent our Rokenbok time using our imaginations to build our own designs. We're going to do the same thing today."

CORE Learning Activity

Have children work in groups of three or four, sharing one Mobile STEM lab. Provide the bill of materials and inventory mats, which the children may or may not find useful.

Remind children of classroom norms you established during the last free build. Especially remind them that there are no "mistakes" when building with ROK Blocks. There are only "improvements" and "do-overs."

Also remind the children about using blocks to reinforce and make things stronger.

You may choose to circulate among the students or build your own creation, or both. As you interact with students ask them to tell you about their creation.

Potential prompt questions:

- What are you making?
- What do you want your object to do?
- Can you show me with your hands what you're trying to make?
- How have you made your object strong?
- Is it symmetrical? How do you know?
- Where are the joints in what you're building? How could you reinforce them?
- What could you do to make it roll?
- What could you do to make it stronger?

If you build your own object, it is helpful for you to "think aloud" about what you're doing, and

CORE Learning Activity (cont.)

to especially comment when you decide to revise your design. Potential Think Aloud comments:

- Oh, I need a lot more Blue blocks than I thought I would need.
- Well, I tested my ______, and it needs to be stronger. I need to reinforce the joints.

Learning Extensions

Free build time offers a great opportunity to connect children's Rokenbok experience with other subjects and skills. If time permits, you can extend children's learning before they build by having them draw or describe what they intend to build.

Also, children can strengthen speaking skills by giving "show and tell" presentations about their creations to their classmates.

They can practice writing skills by taking a picture or drawing their build in their class journals and writing or dictating a few sentences about it. Children can connect to their environment or community by identifying similar objects in their home, school or neighborhood.

Following the free build, take children on a walk through their school and help them identify ways that their school building is reinforced and made stronger (prepare for the walk in advance so you have specific examples to point out to them).

Unit 4 Engineers Make Things Move	Primary Unit Objective: Introduce children to one of the primary tasks of engineering: making things move	Recommended Grades: TK, K, 1st

Developing STEM Identity: In this unit, children explore the physics of movement. They learn about force, gravity, pushes, and pulls. Children learn that when they make things that move, they are acting as an engineer.

Alignment to STEM Standards and Math Learning Progressions Unit 4 focuses on movement and force, fundamental physics and engineering.

Unit Student Learning Objectives (SLO)	NGSS DCI	NGSS SEP	NGSS CCC	CCSS-MA/CA PreK/Math Learning Progressions
SLO 1: Manipulate ROK Blocks to build objects that move	ETSI.B: Developing possible solutions	SEP-2 Developing & using models	CCC-6 Structure & Function	Combine different shapes to make an object or design
SLO 2: Explore a specific problem engineers often face (making things move)	ETSI1.A: Defining/ engineering problems	SEP-1 Asking questions & defining problems	CCC-6 Structure & Function	
SLO 3: Understand pushes/pulls on objects can have different strengths and that bigger pushes/pulls cause bigger changes in the object	PS52.B/PS53.C Pushes/pulls on objects can have different strength; bigger pushes/pulls cause bigger changes	SEP-6 Designing solutions	CCC-3 Scale, proportion & functionality CCC-2 Cause & effect	
SLO 4: Match 3-dimensional objects to 2-dimensional pictures				Recognize 3D objects in 2D pictures
SLO 5: Compare and contrast vehicle types and how different vehicles do work by moving		SEP-3 Planning and carrying out investigations	CCC-3 Scale, proportion & functionality	

Unit 4: Engineers Make Things

Unit 4 Lesson Overviews

Lesson 1: Imagination Land (20 to 30 min)

Children explore how to use Red blocks to make curves and how curves can change directions.

Lesson 2: Tractor (20 to 30 min)

Children construct a tractor to explore different ways that vehicles transport objects and people.

Lesson 3: Helicopter (20 to 30 min)

Children build a helicopter to get acquainted with a vehicle that moves by means of a rotor against gravity.

Lesson 4: Free Build (30 to 40 min)

In this final "free build" experience, children freely explore Rokenbok and are encouraged to create something of their own choosing and to make it move.

Target Vocabulary

Aerospace Engineer	Helicopter	Round
Automotive Engineer	Location	Transport
Curve	Marine Engineer	Transportation
Direction	Movement	Vibration
Drag	Pull	Vehicle
Estimate	Push	Wheel
Force	Rotation	Work
Gravity	Rotor	

Recommended Children's Literature

"Motion: Push and Pull, Fast and Slow" by Darlene Stille and Sheree Boyd

"Pushes and Pulls" by Helen Gregory

"Push and Pull" by Charlotte Guillain

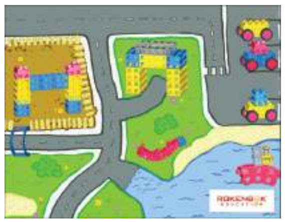
Classroom Organizational Tips

All the lessons in Unit 4 can be taught to the whole class (with or without older student facilitators) or in teacher-facilitated small groups. The lessons are designed to be implemented with small groups of children seated around a shared table. At times it is helpful to have children work in pairs, sharing their observations with their partner. When children use a Rokenbok STEM Mobile lab, there should be no more than four children using each lab.

Unit 4: Lesson 1 Imagination Land

Key Concepts: Engineers can build anything you can imagine. Different engineers specialize in building different things.

Materials per Table



- **Caterpillar Construction Mat**

CORE Learning Activity

First, engage the children in a discussion about curves. "***Today we're going to use some Red blocks to make curves. Can you show me with your body what a curve looks like?"*** [Some children might curve their torso, others might use their arms or legs.] "***Look around the room. Where do you see curves?"*** [Look at door knobs, chairs, corners, tables, etc.]

"A curve can change directions, which means that something is going one way and then it goes another way. Like when you're in a car and the driver turns right or left, or turns around."

CORE Learning Activity (cont.)

Give each student 7 Red blocks and ask them to recall building an arch. Have them use all 7 blocks to build an arch.

Once the arch is ready bring their attention to the fact that all letters (logos) are facing down and that this way this curve has one direction. Ask them to recall what will happen if they keep adding blocks in the same fashion. (they will make a circle)

Now demonstrate taking off 2 blocks from one side and attach them so that the letters on those blocks face up. Ask them if they think they will be able to make a circle now and why not .(because the curve changed directions)

Ask students to "use their imagination" and think what they could make with this shape. (maybe a caterpillar?) Do not disassemble the model yet.

"Engineers use their imagination to build all kind of things. Some engineers use their imagination to build toys. Wouldn't it be fun to be a toy engineer? That's right, engineers built all our toys.

But also, engineers can build almost anything else you can imagine. Different engineers specialize in building different things. For example, remember we built a truck before? Engineers that build trucks are called Automotive engineers. Do you remember we built a bridge and castle walls? Engineers that build building are called Architectural engineers. Now what do you think Marine engineers build?" *(boats, ships). "***Today we will build many different things."***

Assign each child at the table an engineering job.

[Each table will need 2 architectural engineers to build one structure each, 1 toy engineer to build the caterpillar and 1 automotive/marine engineer to build 3 simple cars and 1 small boat. You can adjust the jobs according to the number of students per table.]

Have the student in charge of building the caterpillar continue building on the model from previous exercise. (Each kit has enough blocks for up to 3 caterpillars.)

Learning Extensions

If time allows, encourage students to discuss [and possibly build] other objects or structures that could be added to what they have already built for Imagination Land. Ask students to identify which type of engineer would build each new object/structure.

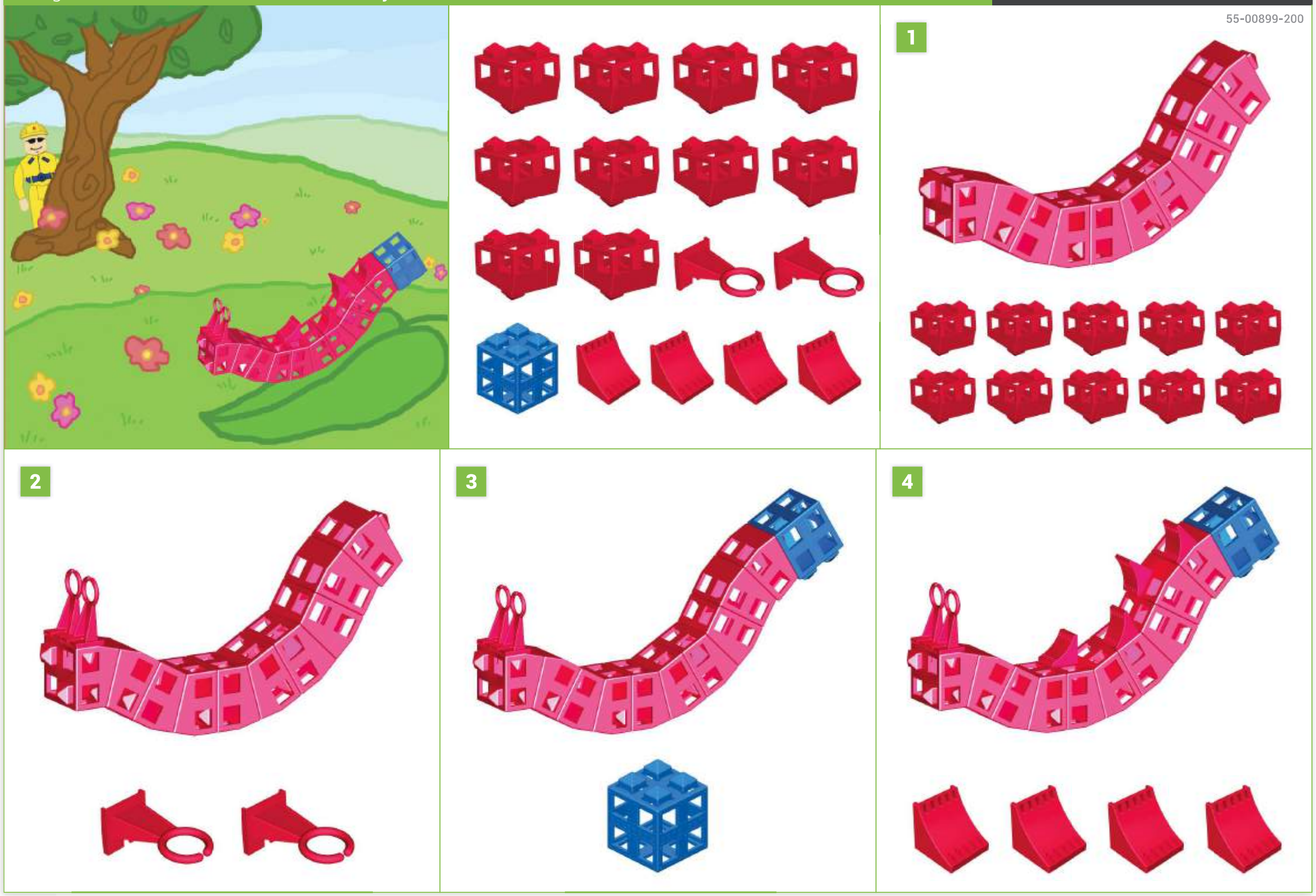
ROKENBOK EDUCATION

Caterpillar

STEM-Maker CURRICULUM v.2.0

Progression: **Mentored Construction Play**

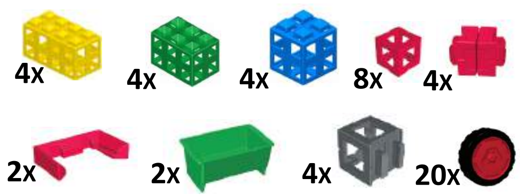
Construction Mat



Unit 4: Lesson 2 Tractor

Key Concepts: Vehicles are things used to transport people or things. Concepts of pulling and pushing.

Materials per Table



- **Modified Tractor Construction Mats**
- **Several extra blocks to experiment with**

CORE Learning Activity

"Remember that a vehicle is used for transporting people or things. Transporting means to move from one place to another. Also remember that engineers have a special way to think about work. Work is the amount of energy it takes to make something move, change directions or stop moving. So, when a vehicle is transporting something, it is doing work.

Today we will make a tractor." Give children the construction mats and blocks to build the tractors through step 3. Ask them to pay special attention to the way yellow and blue blocks are aligned (pyramids up).

CORE Learning Activity (cont.)

After completing step 3 ask children to check each others' models.

Bring the student together into a large group. "***This vehicle can move because it has wheels. Imagine that we need to do the work of transporting some heavy things . How would you do that?"*** (put things on top, push, pull)

"We can put something on top." [Demonstrate with a green block without snapping it on] ***"If we just put things on top when the tractor moves, the vibrations will make things on top fall off."*** [Show how a block can fall off] ***"How could we make sure things don't fall off?"*** (Tie them down, brace them, cover them)

"Those are great engineering ideas. In your Rokenbok kit you have a piece designed by engineers called a box rack ."[Show the box rack and box] ***"Box racks hold things on the top of a tractor so they don't fall off. With the box rack on your tractor, you can transport the green block safely!"*** [Take off the box rack]

"Remember that vehicles do work by pushing and pulling things." Ask the children to remind you of examples of things they "push" to make them move (shopping cart, throwing a ball) and examples of things they "pull" to make them move (a wheeled backpack, cart or cooler). Bring children's attention to the fact that you have to hold/grab something to be able to pull it.

CORE Learning Activity (cont.)

"Let's try pushing with our tractor!" [Demonstrate pushing a green block] ***"We are using a push force on the green block to do the work of moving it."***

"How about pulling? Can our tractors use a pull force to move something? Let's try ."[Place the green block behind the tractor and show the children that the block is not moving] ***"What do we need to do to solve this problem?"*** [Remind children that to pull something you have to grab it or hold on to it.] "***There are lots of ways a tractor could grab something we want to move. In the Rokenbok kit we have a block that engineers designed to do this."*** [Use the axle to hook the green block to the tractor and demonstrate pulling successfully] ***"What other things could we pull with the tractor?***

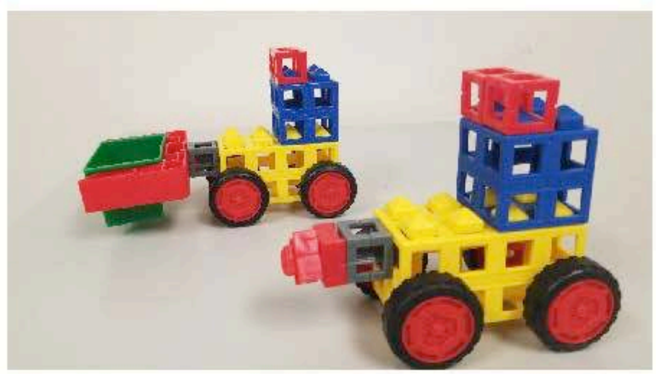
I can even hook up another vehicle with the axle block and pull it!" [You can use another tractor to demonstrate]

Now have children go back to their tables and finish building either tractors that can carry or pull things using the box rack and axle block. If time permits, encourage them to use other blocks to make different objects/models that they can transport with the help of their tractor in various ways.

ROKENBOK EDUCATION

Tractor

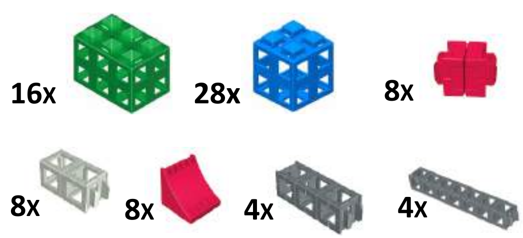
Progression: **Mentored Construction Play** | **Construction Mat**



Unit 4: Lesson 3 Helicopter

Key Concepts: Aircraft engineers build vehicles that can fly. Explore the concept of gravity.

Materials per Table



- **Modified Helicopter Construction Mats**

CORE Learning Activity

"Remember last time we talked about different ways that we can make objects move? We talked about pushing and pulling objects. When a push or a pull moves an object we call that 'force.'"

"Now watch me drop this block." Hold a block in the air and drop it. Pick up the object and repeat. "***What is making this block move?"***

Some children will likely say "gravity" - if so, acknowledge that is right and follow up by asking is gravity a push or a pull? Discuss how the Earth

CORE Learning Activity (cont.)

pulls objects towards its center. "***That force, that pull, is called gravity. Gravity is the reason none of us or the objects around us go floating away.***

In previous lessons we built a lot of vehicles. Can you remind me what kind of vehicles we built?" *(cars, tractor, truck, boat)* ***"We also talked about different types of engineers. Who can remind me what kind of engineer builds cars, and trucks, and tractors?"*** *(automotive)* ***"What does a Marine engineer build?"*** *(ships and boats)* ***"Well today we will be Aircraft engineers. Does anyone know what aircraft engineers build?"*** *(planes, helicopters)*

"What do planes and helicopters do?" *(they transport people and things in the air, they fly in the air)* ***"That's right. Engineers design planes and helicopters to move against the force of gravity and not fall on the ground like our block did."***

Give children the construction mats and blocks to build the helicopter through step 3. Ask them to pay special attention to the way the green and blue blocks are aligned (direction of the pyramid).

After completing step 3 ask children to check each others' models.

CORE Learning Activity (cont.)

Bring the students together into a large group. ***"Does our helicopter have wheels?"*** *(no)* ***"That's right, this helicopter does not have wheels.***

But all vehicles move. How is our helicopter going to move without wheels?" [Draw children's attention to the helicopter's rotor and note that even though the helicopter doesn't have wheels, it still has a part that moves in a circle called a rotor.] "***The rotor goes around, or rotates, very, very quickly. When it rotates quickly it creates a force called lift. The lift that the rotor creates is stronger than the force of gravity, so the helicopter can fly and do the work of transporting whatever is in the helicopter."***

Pick up an axle. "***This is the piece that will help us make a rotor that moves. Helicopters usually have one main rotor and one smaller rotor in the tail. So you will each need 2 axle pieces to build your rotors."***

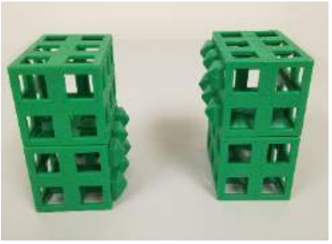
Have the children go back to their tables and finish their builds.

Potential discussion prompts:

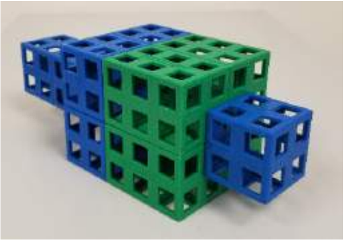
1. What can helicopters do that planes can't do? (Fly straight up. Hover in one place.)
2. Why? (Because the rotor creates lift.)

Unit 4, Lesson 3 Helicopter

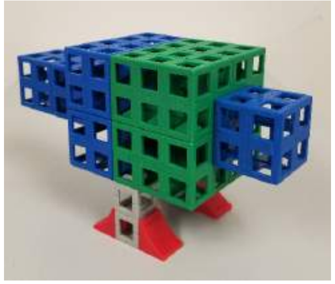
1

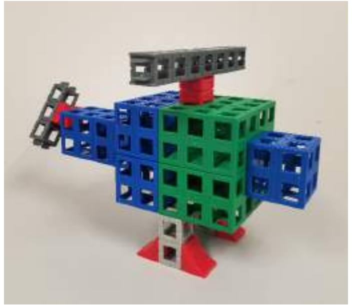


2



3





Unit 4: Lesson 4 Free Build

Key Concepts: We can use our new skills and ROK Blocks to design and build things that move.

Materials per Table

- **Inventory Mats and Bill of Materials**

Introduction

"We've learned a lot about ROK Blocks and how engineers solve problems, design, and build things. Today you get to build whatever you would like again. It would also be great if you could build something strong and something that moves."

CORE Learning Activity

Have children work in groups of three or four, sharing one ROK Block kit. Provide the list of ROK Block Parts and inventory mats, which the children may or may not find useful.

Remind children of classroom norms you established during the last free build. Especially remind them that there are no "mistakes" when building with ROK Blocks. There are only "improvements" and "do-overs."

Also remind the children about using blocks to make things move, and to make them strong.

You may choose to circulate among the students or build your own creation, or both. As you interact with students ask them to tell you about their creation.

Potential prompt questions:

- What are you making?
- What do you want your object to do?
- Can you show me with your hands what you're trying to make?
- How have you made your object strong?
- Is it symmetrical? How do you know?
- Where are the joints in what you're building? How could you reinforce them?
- What could you do to make it roll?
- What could you do to make it stronger?

If you build your own object, it is helpful for you to "think aloud" about what you're doing, and

CORE Learning Activity (cont.)

to especially comment when you decide to revise your design. Potential Think Aloud comments:

- Oh, I need a lot more Blue blocks than I thought I would need.
- Well, I tested my _____, and it needs to be stronger. I need to reinforce the joints.

Learning Extensions

Free build time offers a great opportunity to connect children's Rokenbok experience with other subjects and skills. If time permits, you can extend children's learning before they build by having them draw or describe what they intend to build.

Also, children can strengthen speaking skills by giving "show and tell" presentations about their creations to their classmates.

They can practice writing skills by taking a picture or drawing their build in their class journals and writing or dictating a few sentences about it. Children can connect to their environment or community by identifying similar objects in their home, school or neighborhood.

Following the free build, take children on a walk through their school and help them identify ways that their school building is reinforced and made stronger (prepare for the walk in advance so you have specific examples to point out to them).