**What principles should guide the development of *Seeds of STEM* units?**

Following an extensive review of the literature, the *Seeds of STEM* research team defined a set of eight research-based principles to guide the development of the curriculum and ensure its high quality. The team adapted the Dayton Regional STEM Center's Quality STEM Framework (Pinnell et al., 2013) to meet the standards for high quality early childhood education. A description of the each of the guidelines follows the table below.

<u>Guidelines for High-quality STEM Experiences for Early Childhood Classrooms</u>

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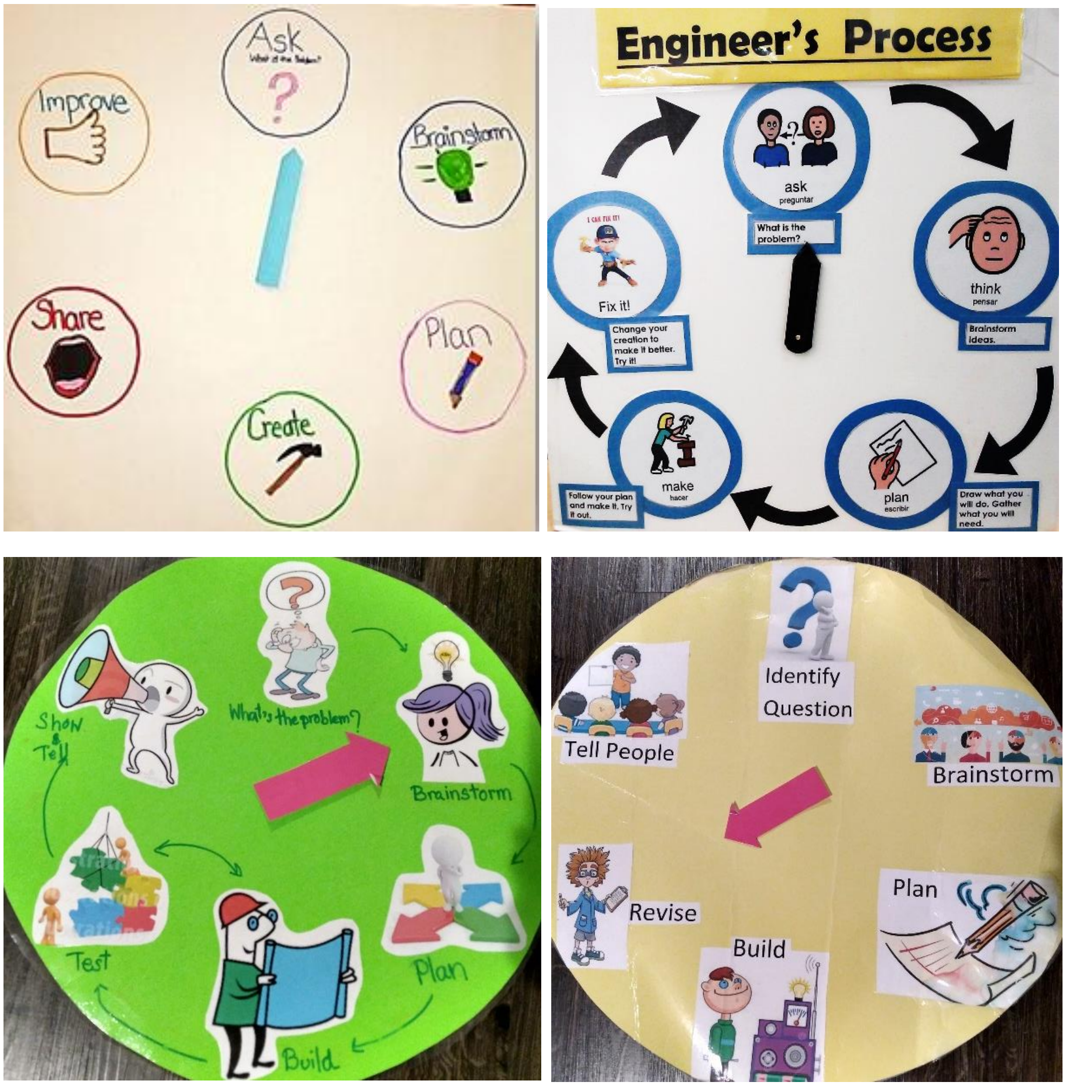
| **1. Developmentally Appropriate** | *Seeds of STEM learning experiences provide children with books, videos, materials, and tasks that are appropriate for their cognitive and language development.* |
| **2. Culturally Responsive** | *Seeds of STEM learning experiences are designed to reflect diversity of gender, ethnic background, and physical abilities while allowing access and emphasizing children's own culture.* |
| **3. Application of the Engineering Design Process** | *Seeds of STEM learning experiences engage children in an* ***open-ended, multiple solutions problem-solving task*** *which requires them to follow the* ***engineering design process*** *(i.e., defining the problem, brainstorming, researching, creating, testing, improving, and communicating).* |
| **4. Integrity of the Academic Content** | *Seeds of STEM learning experiences are content-accurate, aligned with the relevant* ***content standards****, and* ***foundational skills*** *of* ***Science****,* ***Technology****,* ***Engineering****, and* ***Math*** *as articulated in Pre-K standards and frameworks.* |
| **5. Quality of Technology Integration** | *Seeds of STEM learning experiences are* ***hands-on*** *in nature and require children to use variety of* ***tools*** *to solve each problem (e.g., scissors, scales, computers, rulers, hand lenses).* |
| **6. Connections to Non-STEM Disciplines** | *Seeds of STEM learning experiences help children connect STEM knowledge and skills with standards from early literacy, art, social emotional, and physical education.* |
| **7. Real World Connections and STEM Careers** | *Seeds of STEM learning is driven by a real world phenomena, which are familiar and relevant to the children's life inside and out of the classroom.*<br><br>*When applicable, quality STEM learning experiences introduce different STEM careers and help children understand the roles of people who work in STEM disciplines.* |
| **8. Nature of Assessment** | *Seeds of STEM units include formative and summative authentic embedded assessments. The variety of activities allows children to demonstrate their understanding in different ways and allows teachers to record children's mastery of learning outcomes.* |

*Developmentally appropriate.* Head Start classrooms are comprised of children of various ages, and often include a wide range of skills, abilities, and language backgrounds (Cabell et al., 2011). To ensure that each unit of the curriculum is developmentally appropriate the team relied on the National Head Start Child Development and Early Learning Framework (2010), and the Massachusetts Framework for Science, Technology, and Engineering for Pre-K (2014) to define the learning outcomes of the curriculum. The developer teachers proposed activities and tasks that cater to their multi-age and multi-ability classrooms. Through the iterative process of trial, feedback, and revisions, we were able to select only the activities that were proven to engage all children, including children who are dual language learners (DLLs). To increase engagement with the curriculum, the development team created a character, Problem Panda (exemplified by a stuffed animal), that visits the children in each unit to present a new problem.

*Culturally responsive*. Research shows that cultural contexts affect young children's cognitive, social, and emotional development, as well as their approaches to learning (Bowman, Donovan, & Burns, 2001; Genishi & Goodwin, 2008). A school's culture may differ greatly from a minority group's home culture. New (1999) called for early childhood teachers to embrace children's home culture and model the coexistence of different cultures. This allows children of minority cultures to value their home culture and the school (majority) culture, and learn to celebrate the differences in people's identities. Culturally-based education recognizes the language, experiences, values, and knowledge of children, their families, and their communities, and includes elements of children's home culture into the daily curriculum (Dubosarsky et al., 2011). The *Seeds of STEM* curriculum addresses cultural responsiveness by using books, images, and scenarios that represent a diversity of cultures, allowing children to identify and feel included in the units, while learning to respect other cultures. In addition, research suggests that parent-teacher collaboration supports student learning, and parental involvement is associated with academic and social competence (Powell, Son, File, & San Juan, 2010). To build on these findings, each unit plan includes extension activities and home-connections ideas for engaging the family with the topic of the unit.

*Application of the Engineering Design Process.* The research team strongly believes that the process of problem solving is the heart of STEM education, and therefore the process should be taught explicitly through the curriculum. The problems that are presented to the children should be open ended and allow for multiple solutions. To support the curriculum's mission of teaching children how to solve problems, and with full understanding that the process may be too abstract for young children, *Seeds of STEM* engages the teachers in creating a visual aid of the problem-solving process. The visual, which looks differently in each classroom, is introduced during the first unit and being referred to multiple times in every unit of the curriculum. The teachers created the problem-solving visuals during a workshop, using vocabulary words and images that fit their students' understanding. It was important to the research team that every classroom team will create their own visual, thus increasing the ownership of teaching the process. A few examples of teachers' visuals are found in figure 2.

Figure 2: visuals of the problem-solving process




*Integrity of academic content.* Based on the authors' experience of conducting STEM professional development workshops with P-12 teachers, often times STEM projects are designed as 'add-on' experiences, for example 'egg drop' or bridge building challenges, without making clear connection between the STEM challenge and the instructional core ideas (academic standards). The *Seeds of STEM* problems and tasks are aligned with science, math, or literacy standards, in order to make connections between STEM (engineering in particular) and the rest of the pre-K curriculum, and prepare children to become problem solvers in any subject. As described earlier, each one of the *Seeds of STEM* units is aligned with NGSS core-ideas, as well as the MA science, technology, engineering standards for Pre-K, and the Head Start Framework.

The problems presented to the children require them to apply the science and math concepts for creating successful solutions.

*Quality of technology integration.* A common misconception held by educators (and the general public) narrow the definition of technology to digital-technology. However, the technology integration principle calls for using tools, any kind of tool, that children find useful in solving the problem. These tools may include scissors, a scale, child-sized hammer, marker, measuring tape, spoon, camera, as well as a computer or tablet for research. Teachers who follow the *Seeds of STEM* curriculum consider the tools that children can use safely and include a plan on teaching the children how to use these tools.

*Connection to non-STEM disciplines.* Integration is key to STEM education and the curriculum reflects that by using non-STEM context, such as books, videos, stories, and social studies topics, to generate problems. A study involving kindergarten students found that integration of science and literacy increased children's motivation and engagement in science (Samarapungavan, Mantzicopoulos, & Patrick, 2008). William Wolfson's *Engineering Lens* method (http://www.integratingengineering.org/index.html) for integrating engineering practices with literacy was used by the research team during the development process. There are several advantages for the integration of STEM with literacy: First, greater engagement from teachers, who are very comfortable with literacy activities. Second, this approach may help overcome common stereotypes (i.e., engineering is building). Third, using books as a context to start the problem-solving process allows for the choice of books that represent real-world relevance and involving a diverse population of characters. Fourth, adding books as the context for problem solving assists with daily lesson planning since it is expected to address literacy daily.
In addition to integration of STEM with literacy, the *Seeds of STEM* curriculum includes arts, music, and physical activities to the curriculum. The children go on a force hunt (forces and motion), shadow hunt (light and shadow), and solid/liquid hunt (ice and water) around the school, and end many of the daily activities with 'freeze dance' that helps emphasize some of the concepts through kinesthetic learning.

*Authentic assessment.* Since the *Seeds of STEM* curriculum is centered on STEM practices, authentic assessments that are embedded in the unit would measure children's mastery of learning outcomes. Each unit plan includes formative assessment tasks that asks children to explain, demonstrate, or design a solution to a problem. The teachers document children's learning by scribing their explanations on the plans. The teachers also record children's demonstration of the problem-solving steps and use of vocabulary in context. Since young children may show evidence of transfer of the learning during other parts of the day, each unit includes a checklist of learning outcomes and the teacher is able to record evidence for learning – such as using the unit's vocabulary or demonstrating a key skill – throughout the day.

The repetitive nature of the curriculum, and the emphasis of the problem-solving process, engages the children in solving problems with different contexts. The last unit of the curriculum also serves as authentic summative assessment, allowing the teacher to evaluate children's mastery of the curriculum's learning outcomes.