Early Childhood
STEM Working Group

Photo by Loren Santow

Early **STEM** Matters

Providing High-Quality STEM Experiences for All Young Learners

A Policy Report by the Early Childhood STEM Working Group

January 2017

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The Early Childhood STEM Working Group includes scholars, policymakers, curriculum developers, and educators from around the United States who share a vision and goal for universal access to high-quality, developmentally appropriate STEM education for preschool children. With so much attention focused on early childhood education and STEM education separately, the aim of the Working Group and of this report is to help guide and inform discussion about their intersection: to build on current momentum and public discourse to create and enact an ambitious but achievable vision for the future of young children's STEM education.

The Working Group's organizing committee, comprised of its members from Erikson Institute and UChicago STEM Education, facilitated Working Group meetings and coordinated drafting and editing the report. UChicago STEM Education's **Elizabet Spaepen** served as the lead author of the report.

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Executive Summary

Introduction

The Early Childhood STEM Working Group is a group of scholars, policymakers, curriculum developers, and educators who share a common goal and vision of universal access to high-quality, developmentally appropriate STEM education for preschool children. The Working Group met over a two-year span to pool knowledge about the development of STEM concepts and practices during the early years, discuss ways to support early STEM education, and make achievable recommendations to promote research, practice, and advocacy that will lead to high-quality STEM experiences for all young children. This report is the culmination of those efforts.

Early childhood education and STEM education are both at the forefront of recent education discussions in the policy realm and in the media. But they are rarely talked about together, despite important overlaps. High-quality early childhood education must include attention to science, technology, engineering, and mathematics. And, just as with language and literacy, STEM education should start early in order to maximize its benefits and effectiveness. With so much attention focused on early childhood education and STEM education separately, our aim in this report is to build on the current momentum and public discourse to create and enact an ambitious but achievable vision for the future of young children's STEM education.

The report is intended to provide guidance to education leaders, including school and district leaders and decision makers, policy makers at the local, state, and federal levels, researchers, and those who fund education initiatives. It offers four guiding principles and six actionable recommendations. The guiding principles are overarching conceptual commitments about young children and STEM education. They reflect our larger philosophy regarding early childhood STEM education and are embedded in each of the six recommendations. The recommendations identify specific steps involving policy, practice, and research that will promote dramatic improvement in early STEM education for all young children.

Guiding Principles

1

Children need adults to develop their "natural" STEM inclinations.

Although young children often show great natural curiosity about the world and remarkable capacity to learn on their own, they need adult assistance to foster, guide, and build on their interests to ensure adequate early STEM experiences.

2

Representation and communication are central to STEM learning.

STEM education must feature discussion, visualization, and other forms of representation (e.g., drawing, writing, graphing) to promote learning that leads to generalization of important concepts and practices.

3

Adults' beliefs and attitudes about STEM affect children's beliefs and attitudes about STEM.

Many people in the United States believe they are not competent or skilled in STEM-related fields, may avoid these areas, and may even profess this claimed incompetence in social situations. It is important to work to change these attitudes and beliefs by building adults' and children's self-efficacy around their ability to learn and do STEM, especially in groups that are traditionally under-represented in STEM careers, such as women and minorities. Doing so will lead to higher-quality STEM education now and in the future.

4

STEM education is not culturally neutral.

Although mathematics is sometimes claimed to be a "universal" language and science is sometimes seen as "objective," STEM education is not culturally neutral. It is subject to the same types of cultural influences and cultural, racial, and class biases and stereotypes as other topics in education. Adults' explicit acknowledgment of and willingness to address these issues will mean more recognition of culturally different approaches to STEM education and will reduce biases and stereotypes that limit children's success as STEM learners.

Recommendations

RECOMMENDATION 1

Messaging

Raise the profile and understanding of early childhood STEM education via advocacy and messaging.

Generating broad support for young children's access to high-quality STEM experiences begins with sparking awareness and discourse about it. This in turn will create demand for high-quality STEM in preschools from key stakeholders, including parents, teachers, administrators, and policymakers.

RECOMMENDATION 2

Teacher Preparation

Revamp pre-service and in-service STEM-related training and supports for early childhood teachers.

For all children to have access to high-quality STEM experiences in preschool, their teachers need to be well-prepared in both content and pedagogy to lead high-quality STEM experiences in their classrooms. We must revamp early childhood program and teacher accreditation requirements to include preparation and continuing support in the STEM disciplines.

RECOMMENDATION 3

Parents and Families

Establish initiatives, resources, and supports that promote parents' and families' involvement and engagement in their young children's STEM education.

Parents play a key role in shaping children's early experiences in STEM at home, and in creating demand for high-quality STEM education in their children's early childhood settings. Too often, parents lack the knowledge or confidence to support children's early STEM education. We need robust supports that build adult and child self-efficacy around STEM, inspire family involvement in STEM at home, convey the importance of STEM experiences in early childhood, and empower families to expect and advocate for high-quality STEM education in their children's schools.

Recommendations

RECOMMENDATION 4

Classroom Resources

Make high-quality early STEM resources and implementation guidance available to practitioners.

Early childhood educators too frequently lack access to high-quality STEM education resources, lack guidance about what makes STEM resources high quality, and lack support for using available resources effectively. Educators need clear and concise information about what constitutes a high-quality STEM resource, and they need access to and support for implementing existing and newly-developed high-quality resources.

RECOMMENDATION 5

Standards

Ensure that early learning and development standards explicitly address the STEM disciplines and align with K-12 standards.

State-level early learning standards and guidelines currently vary in their recognition of STEM disciplines as areas of focus for young children's learning, and in their alignment to K–12 standards in science, technology, engineering, and mathematics. Standards and guidelines influence teachers' and principals' priorities for their youngest students. If STEM is recognized and highlighted in early learning standards, it will bring increased attention and time to those areas in preschool. If the standards are well aligned with K–12 standards, it increases the likelihood that children's preschool experiences will prepare them for what they will be asked to do in kindergarten and beyond.

RECOMMENDATION 6

Research

Develop and support a research agenda that informs developmental trajectories, effective resources, and best practices in early childhood STEM education.

A firm research foundation is needed to guide policies and investments related to early childhood STEM education. Funding agencies should prioritize research that will fill current gaps in knowledge about science, technology, engineering, and mathematics teaching and learning in early childhood. This includes support for researcher-practitioner partnerships to help ensure that high-quality research addresses the realities of early childhood classrooms, and that the findings reach those who need it, namely teachers, administrators, curriculum developers, professional development providers, and pre-service teacher educators. Research findings can be made accessible to these audiences in forms such as curricula, professional development materials, and products that practitioners can use to enhance their work.

Introduction

In recent years, both STEM education and early childhood education have been at the forefront of national discussions about educational policy. This document links those discussions, focusing on the current state of STEM education for children who are 3–5 years old and making recommendations about how to improve early childhood STEM education. Preschool settings are the primary focus, but the principles and recommendations in this document can also apply to other early care settings, including home environments.

There is limited high-quality practical guidance to drive effective practice for early childhood STEM education, and access to this guidance is not distributed equally across the spectrum of early childhood programs. Further, answers to important questions remain elusive. For example: *What are the natural capabilities that young children possess for acquiring and developing their understanding of STEM concepts? What are the precursor practices that will enhance children's learning in different STEM disciplines? Are some STEM concepts more foundational and therefore more critical than others in the early years of learning? What kind of educational experiences are conducive to young children's knowing and understanding the foundational STEM concepts? How can we engage young children in authentic, interdisciplinary STEM learning experiences instead of isolated activities that are disconnected from one another and from a meaningful context?*

These and other questions about STEM education for young children were the focus of the Early Childhood STEM Working Group—scholars, policymakers, curriculum developers, and educators from around the United States who share a common vision of universal access to high-quality, developmentally appropriate STEM education for preschool children. This report represents the views of this group, which grew out of the existing research base and our pooled knowledge about the development of STEM concepts and practices during the early years, as well as extensive discussions about ways to support early STEM education. It makes a set of achievable recommendations to educational leaders, policy makers, researchers, and funders to promote research, practice, and advocacy that will lead to high-quality STEM experiences for all young children.

The Promise of Early Childhood STEM Education

With so many competing interests, concerns, and important topics to teach in preschool, why focus on the STEM disciplines?

First, early investments in STEM pay off. While not enough longitudinal research exists to track the effects of early experiences in each of the STEM disciplines, several studies have shown that children's mathematics achievement at kindergarten entry predicts later math and literacy achievement even more than early literacy ability does. Further, high-quality STEM experiences provide young children with opportunities to develop critical thinking, executive functioning, and problem solving skills that cut across subject areas (within and outside of STEM disciplines) and that set the stage for how they approach learning and thinking about rich content into the future. These experiences also provide children with engaging, motivating, and relevant contexts in which to practice and learn many of the other skills they are working on, including their emerging language and literacy skills.

Research has found that children from different socio-economic circumstances enter kindergarten with large differences in math and science knowledge, and that these differences tend to persist—even grow—over time. However, these differences can be ameliorated through school and home experiences that promote disciplinary talk, teach foundational concepts, skills, and practices, and develop confidence, interest, and other positive dispositions about STEM. In other words, intentional inclusion of STEM experiences in early childhood can prevent these dangerous and persistent early learning gaps in STEM areas.

Second, children's attitudes about STEM and about themselves as STEM learners are formed early. Children's earliest experiences with science, technology, engineering, and mathematics set the stage for their later engagement and success in those fields; if we fail to give all children access to high-quality early STEM experiences, instead providing either inferior quality STEM experiences or no STEM at all, they may very well lose interest in STEM topics or lose confidence that they can "do" STEM. Because children often inadvertently receive both subtle and not-so-subtle negative messages from adults about STEM, providing positive opportunities early to shape their attitudes and beliefs about their ability to succeed in STEM matters all the more. Children who have early experiences at home, in preschool, and in other child care settings that help them learn that they are capable STEM learners are more likely to engage in later STEM instruction with confidence, curiosity, and understanding of foundational STEM practices.

What is STEM Education in Early Childhood?

The STEM disciplines—science, technology, engineering, and mathematics—share a set of foundational processes and practices. Many of the central concepts, practices, and dispositions of the STEM disciplines build on and are connected to one another. At the same time, the STEM disciplines are distinct, with discipline-specific characteristics and knowledge.

The connections across the STEM disciplines and the distinct features of each have implications for early childhood STEM education. Each discipline warrants subject-specific attention to ensure that children build their foundational subject-matter knowledge systematically and to highlight the creativity, beauty, and unique features of the discipline itself. And yet, there are rich and valuable opportunities for integration across STEM disciplines. The best "integration" typically involves one discipline in the foreground (i.e., the focus of the activity) and one or more other disciplines serving as background.

As early childhood educators, we acknowledge the complexity of the notion that there are strong connections across the STEM disciplines, but also that these disciplines are distinct in ways that matter for teaching and learning. We suggest an educational approach that acknowledges both the connections and the distinctions, and that helps teachers provide experiences and teach skills that will create a solid foundation upon which to build later deeper understanding. We also note that many of the commonalities across the disciplines align well with a developmental approach to early childhood education, namely an emphasis on active engagement with the natural, physical, and social worlds. These synergies between and across the STEM disciplines and early childhood education can be used to provide young children with rich, authentic STEM experiences that are sometimes integrated and sometimes distinct, just as they are in the real world.

INTEGRATING STEM CONTENT AREAS

When children measure the size of pumpkins as they grow, teachers may foreground science by emphasizing what helps plants grow, while still integrating mathematics in the background as children explore and discuss ways to measure and describe the size of the pumpkins. This same activity can foreground mathematics if teachers focus children's work and attention on concepts and procedures in measurement, using pumpkin growth as an interesting context in which to learn about and practice mathematics. Deciding whether and when to teach topics in mathematics, science, and engineering separately or as part of integrated activities requires special consideration of developmental trajectories within each individual discipline. Successful integration across two or more STEM disciplines is challenging and requires deliberate planning, more than is often acknowledged by advocates of a wholly-integrated or thematic approach.

Technology
in early childhood classrooms

In this report, we define technology broadly to mean anything human-made that is used to solve a problem or fulfill a desire. Technology can be an object, a system, or a process that results in the modification of the natural world to meet human needs and wants. From our perspective, technology in the classroom, in informal learning environments, and at home includes both analog tools such as a pencil or a wooden block, and digital tools, including tablets and digital cameras, microscopes, tangible technology, and simple robotics. In the digital age, the focus has become new screen-based technologies and interactive media. However, in the context of STEM, educators need to consider all the ways they use technology as a tool for learning and the affordances of new digital tools that make it possible for a child to move from media consumer to media creator.


Photo by Loren Santow

We hold that the “T” in STEM—technology—should be considered differently from the other disciplines. Technology is not a content area to be studied by young children but rather an important tool that can support learning in the STEM disciplines and across the curriculum. In using digital technologies with young children, we recommend a progression that begins with learning how to use technology tools in the same way that we promote book-handling skills in early literacy. The next step in the progression is when children use technologies as tools for their own exploration of the world and inquiry about things that interest them. Children’s interactions with technology and digital media should focus on using them for exploration, discovery, documentation, research, communication and collaboration. As children approach school age (K–3), the third step in the progression is learning about technology; this opens up opportunities for developmentally appropriate introductions to coding and computational thinking as part of the early school experience and expectations.

Overview of the Report

This report offers four guiding principles and six actionable recommendations. The guiding principles are overarching conceptual commitments about young children and STEM education. At the same time, they are specifically intended to correct larger misconceptions about STEM disciplines that currently abound in early childhood. These principles generally reflect best practices for early childhood education that are often overlooked or forgotten in STEM education.

The six recommendations for action, while embedding the guiding principles, target key steps for policy, practice, and research that will promote dramatic improvement in early STEM education. They are intended for school leaders and district decision-makers, policymakers at the local, state, and federal levels, researchers, and funders. Our aim is to help guide discussion and change at a critical point in public discourse about the need for high-quality early childhood STEM education.

Guiding Principles

1 Children need adults to develop their "natural" STEM inclinations.

Although young children often show great natural curiosity about the world and remarkable capacity to learn on their own, they need adult assistance to foster, guide, and build on their interests to ensure adequate early STEM experiences.

Children are often considered "natural scientists and engineers."

They are inherently curious and equipped with basic capacities and dispositions to make sense of the world around them. They design forts, divert water from puddles, develop obstacle courses, and otherwise creatively solve problems. However, their curiosity about and drive to make sense of the world can be misconstrued as innate scientific thinking. These natural abilities are necessary to develop understandings of STEM disciplines, but they are not sufficient. Children may be curious to explore and eager to affect the world around them, but without support, their curiosity does not persist or motivate sustained investigation. Children ask questions, but they may abandon those questions readily when they do not discover answers quickly; similarly, they may give up when the solutions they design do not work well the first time.

To support children's development, adults model genuine, ongoing interest in the world, frequently asking questions about why and how. They help children define a problem they might solve, think about the goal, and encourage them to persist when designs fail. They ask questions that do not occur to children, and they model how to use relevant language and other tools. They provoke, challenge, and extend children's curiosity, interests, and thinking.

Adults are also needed to promote the development of disciplinary knowledge in STEM. They expose children to memorable, sustained, and relevant experiences, using carefully selected materials and phenomena that help children make sense of the world. They also provide typical and atypical examples of natural phenomena to help children generalize their learning.

This is not to say that all of children's naive concepts—the concepts developed based on their limited experience and a messy real world—are bad and need to be immediately corrected by adults. Children's naive concepts signify important developmental milestones, and they can be used as mediators to understand scientific concepts. Too quick "correction" of such concepts may lead children to develop a lack of confidence in their own ability to explore, think, and draw conclusions.

The knowledge that children acquire on their own makes sense, given their experiences and perspectives, but does not always lead smoothly to ongoing learning. Adults play an important role in understanding how and when to ask the next question, remind children of a counterexample, or sometimes even just add a new fact or piece of information that children do not know (e.g., "Some seeds fly on the wind, some get stuck on an animal's fur and carried, and some float on rivers and brooks.").

Through these types of guided experiences, children learn to think, calculate, and create like scientists, mathematicians, and engineers. Rich, adult-facilitated STEM experiences in preschool help children develop the skills and habits of mind that will prepare them for later competencies in STEM disciplines.

Guiding Principles

2 Representation and communication are central to STEM learning.

STEM education must feature discussion, visualization, and other forms of representation (e.g., drawing, writing, graphing) to promote learning that leads to generalization of important concepts and practices.

Instruction in the STEM disciplines often over-emphasizes procedural competencies and “hands-on” experiences—applying an algorithm to a set of practice problems in a math workbook, measuring and combining ingredients when studying chemistry, or testing a solution in engineering—and under-emphasizes communication about those activities and representations that stem from the activities, such as drawing pictures, making data tables and graphs, and writing numerical representations. While hands-on activities are necessary parts of studying STEM disciplines, they do not, in and of themselves, activate thinking and conceptualization.

Communication about such activities can lead to generalization and to the production of ideas that allow children to apply their understanding in new situations. This is because communication requires the representation of actions or procedures in language or some other form that helps highlight commonalities and differences. Representations are essential tools in STEM that can also make it possible to notice things that otherwise could not be perceived, such as changes over time, patterns or trends across examples, and so on.

Further, children need experiences with communication and documentation so they can learn how to make their own understandings explicit and sometimes to challenge or extend initial understandings—an important skill in all fields, including STEM. Generating questions, constructing and critiquing arguments, reaching conclusions, drawing inferences, building generalizations, and justifying claims, theories, and design decisions are all natural extensions of good STEM learning that can help children develop their communication and representational skills. And as they communicate their thinking in these ways, students make connections among STEM ideas and generalize meaning, both for themselves and those around them. These sorts of experiences also contribute to children’s language and literacy development in meaningful and powerful ways.

Communication can lead to generalization and production of new ideas.

Representation in preschool

Children should be encouraged to talk about, write about, draw, map, measure, and, in a variety of ways, symbolize their ideas. Different ways of representing often expose new aspects of thinking. When children develop their representational repertoire, it helps them build critical STEM tools—STEM professionals also rely on blueprints, maps, diagrams, and mathematical formalisms. Representations need to develop hand in hand with children’s growing sense of audience. Children should have opportunities to communicate in various formats and to work with peers to interpret, ask questions, and compare/contrast what their own representations “show and hide.”

Note how this child’s two drawings convey different views of the same plant. The first highlights what the dandelion looks like above ground; the second reflects the child’s fascination with the taproot, which is not visible unless the plant is uprooted.

Guiding Principles

Photo by Loren Santow

3 Adults' beliefs and attitudes about STEM affect children's beliefs & attitudes about STEM.

Many people in the United States believe they are not competent or skilled in STEM-related fields, may avoid these areas, and may even profess this claimed incompetence in social situations. It is important to work to change these attitudes and beliefs by building adults' and children's self-efficacy around their ability to learn and do STEM, especially in groups that are traditionally under-represented in STEM careers, such as women and minorities. Doing so will lead to higher-quality STEM education now and in the future.

People often think that ability in the STEM disciplines is fixed—that achievement in math, for example, is based on innate ability, rather than on learning and on other factors that can be controlled, such as effort and persistence. This leads many people, disproportionately women and others who are traditionally underrepresented in STEM careers, to be anxious about their abilities in these disciplines, and to react by removing themselves from experiences that involve math, science, or engineering. It also leads to adults referring to children's abilities in STEM in fixed ways, such as their being "good at" or "not good at" STEM disciplines, rather than focusing on their effort and persistence.

Modest interventions can help promote positive mindsets about STEM.

Children's dispositions to engage in STEM with confidence are often disrupted negatively by their parents' and teachers' own STEM anxiety. Teachers' and parents' lack of content knowledge and fear of STEM topics can result in avoidance of teaching, talking, and thinking about challenging STEM topics. It can also contribute to the inadvertent, often subtle or subconscious transmission of low STEM expectations and achievement, especially to young girls, to English language learners, or to children from poor families or from families with low levels of education. We can help prepare adults to develop positive STEM mindsets in all children by honestly addressing these issues, and through deliberate efforts to build teachers' and parents' confidence and competence in their own STEM abilities. Through helping adults change their attitudes, we will improve children's confidence that they can become successful STEM learners, but this is an issue that must be directly addressed.

Research shows that modest interventions with both adults and children can help promote positive mindsets about STEM by targeting issues such as the value of effort and persistence, how mistakes can be helpful to learning, and the benefits of productive struggle. It is crucial that these interventions begin early if we want to interrupt the negative patterns that currently dominate attitudes in the STEM fields.

Overcoming parental math anxiety

When parents or teachers are anxious about math, children actually learn less math. Notably, research suggests that when math-anxious parents frequently help their children with homework, their children's math achievement can suffer. This pattern contrasts with the effects seen in non-math-anxious parents and children, who are not negatively affected by their parents' homework help. Fortunately there are ways to help math-anxious parents have productive math conversations with their children that build their children's math skills. One way is to provide them with semi-scripted materials that lead to productive math discussions. For example, one study showed positive results from families who used a free app that provides interesting contexts and associated math problems for families to do together. Children of math-anxious parents who used this app learned as much math over the school year as children of non-math-anxious parents. Moreover, the math-anxious parents began to value math more for their children and expected them to perform better in math, attitudes that are associated with sustaining children's math achievement over time.

GUIDING PRINCIPLES

4 STEM education is not culturally neutral

Although mathematics is sometimes claimed to be a "universal" language and science is sometimes seen as "objective," STEM education is not culturally neutral. It is subject to the same types of cultural influences and cultural, racial, and class biases and stereotypes as other topics in education. Adults' explicit acknowledgment of and willingness to address these issues will mean more recognition of culturally different approaches to STEM education and will reduce biases and stereotypes that limit children's success as STEM learners.

Even young children receive messages, in and out of school, about their potential for successful participation in STEM based on group membership (e.g., children of Asian ancestry being seen as "good" at math, boys being seen as more adept at engineering than girls). These messages can often be subtle and unintentional, such as boys receiving gifts of blocks and construction sets, and girls receiving dolls and play kitchens. However, they are potentially damaging nonetheless, since they influence adults' perceptions of and interactions with children, and can influence children's own perceptions of themselves.

Many STEM activities fundamentally lend themselves to inclusion.

Children come to school with different foundational STEM experiences, with cultural belief systems that may conflict with common teachings of a discipline, and with differing amounts of experience with English. These variations in children's experiences influence how they understand their school experiences with new STEM concepts and practices, and adults must be tuned in to help children build strategies to resolve conflicts and contradictions.

Our knowledge about the ways that STEM subjects are introduced and taught must continue to evolve in order to make them inclusive and culturally sensitive for all children. Many STEM activities fundamentally lend themselves to inclusion, as they often give children direct experiences with the natural and human-made world. But educators must continue to strive for cultural inclusivity in STEM by supporting a culture of collaboration and teamwork. This includes welcoming joint contributions and considering how to help all children develop familiarity with the materials and terminology they use. Children can also learn to participate and identify as scientists, engineers, or mathematicians through exposure to STEM role models representing different genders, races, and cultural affiliations. Attention to these issues will help all children begin school with confidence in their ability to participate and flourish in the STEM disciplines.

Teaching and learning about seasons through a new cultural lens

This was in a very rural area and I (the teacher) was a bit out of touch culturally with the children and families I was working with. While doing Circle Time in front of a large display of "the Seasons" one of the children asked: "What is that?" "It's about seasons." I responded. He looked blank and asked, "What is seasons?" I proceeded to try to describe fall, winter, spring, summer. He still looked blank and said, "I don't think we have that here." I persisted with, "You know, in the Fall the leaves fall off the trees and they crinkle when you walk through the forest" (trying to add important images and vocabulary to the conversation). Suddenly, the child jumped up and yelled, "Ohhhhhh! You mean deer season! Okay, there is deer season, then elk season, then rabbit season, then trout season, then salmon season…." he went on and on, his face lit up with recognition and accomplishment. This teacher, new to this place, and from a decidedly urban background, had finally hit on something that was culturally relevant for this child.

From Katie Kissinger: ***Anti-Bias Education in the Early Childhood Classroom: Hand in Hand, Step by Step.*** *Routledge Publishers, in press 2017.*

RECOMMENDATION

1

Messaging

Raise the profile and understanding of early childhood STEM education via advocacy and messaging.

Generating broad support for young children's access to high-quality STEM experiences begins with sparking awareness and discourse about it. This in turn will create demand for high-quality STEM in preschools from key stakeholders, including parents, teachers, administrators, and policymakers.

WHERE WE ARE

Within the field of early childhood, instruction in the STEM disciplines is often sacrificed in favor of a focus on other curricular areas, particularly early literacy. This leads to insufficient advocacy for and attention to early STEM learning among policymakers, education leaders, teachers, parents, and researchers. The result is a problematic cycle of low prioritizing of early childhood STEM at all levels of our early education system.

Each of the STEM disciplines faces unique challenges and is at a different point in its incorporation in preschool classrooms. Mathematics has seen the most attention, sparked in part by advocacy from educators, early childhood experts, and policymakers. This advocacy has resulted in increased time spent on mathematics in preschool, and more math resources and curricula available for teachers. This work has also shown that more emphasis on STEM topics does not sacrifice children's learning about language and literacy. We are far from ensuring that all children receive high-quality mathematics experiences in preschool, but the success and momentum achieved in mathematics reform can serve as a partial model for increasing and improving science, technology, and engineering education in early childhood.

WHERE WE WANT TO BE

Educating the broader public about the importance of early STEM education and generating broad excitement about early STEM will result in increased dedication, motivation, and resources to improve teacher preparation, generate more and better research about early childhood STEM education, and inform better state- and federal-level standards for STEM in preschools.

STEPS TO GET US THERE

Develop and prioritize a national STEM agenda for preschool. State- and national-level policy leaders must collaborate with early childhood experts to develop a meaningful agenda for incorporating STEM disciplines into preschool programs. This agenda should emphasize developmentally appropriate experiences in the STEM disciplines for young children and adequate professional development for pre-and in-service early childhood teachers. A clear, unified agenda for STEM education for young children can help allocate attention, resources, and time in efficient and goal-directed ways.

Develop and implement a media campaign with a united message about the importance of early childhood STEM education. A broadly based consortium of policy and advocacy groups in early childhood education and in STEM education should convene to develop a media campaign around a united message about the importance of STEM experiences in preschool. Such a campaign should incorporate a slogan that captures the excitement and urgency of the need to expand STEM programs for all young children, and promote stronger public engagement with the issue. It should also explicitly counter the widely held belief that STEM is only for older children, and not even for all of them.

Components might include editorials in newspapers and magazines, advertising campaigns on public transportation vehicles, a website for parents to get information about what to expect from their preschools with regard to STEM, and dissemination of information via social media. Such a media campaign, similar to those aimed at heightening public awareness about reading to young children, will help direct key stakeholders' attention to an urgent problem, and create demand for more funding and access to high-quality STEM education for all young children.

Monitor and adjust the campaign to ensure its broad reach and focused message. Messaging and advocacy do not effect change overnight. Changing the public discourse about the important role of STEM in early childhood will take time, and it is incumbent upon key stakeholders to monitor and adjust the advocacy and messaging campaigns based on their successes and failures. This may include changing venues and strategies where messaging is focused, increasing the messaging aimed at targeted audiences, inviting new governing bodies and stakeholders into the campaign, and so on.

Education reform is prone to fads, and they are often declared to have failed before they are given adequate time to succeed. As we begin to raise the profile of STEM education in early childhood, we must be dogged in maintaining a clear and consistent message over time, so that it remains in the public discourse. In addition, we must be vigilant about the kind of change it effects: Are teachers receiving high-quality training in the STEM disciplines? Are children's STEM experiences in accord with current research about how they learn and build on their natural curiosity?

Develop support materials to help key stakeholders understand what high-quality STEM education is. Researchers and practitioners must help key stakeholders—from parents and the general public to preschool directors and education policy advocates—recognize what high-quality preschool STEM looks like and convince them that it matters. Toolkits should be developed that include: short descriptions of research highlighting the importance of early STEM experiences; examples, including video, of what high-quality STEM looks like in preschool classrooms; profiles of organizations and schools that are incorporating STEM experiences in preschool; and reflections from parents, children, teachers, and administrators about the impact of high quality, early childhood STEM programs. These resources will help build constituencies who know what to expect with STEM education and why such instruction is valuable and essential for all children.

RECOMMENDATION

2

Teacher Preparation

Revamp pre-service and in-service STEM-related training and supports for early childhood teachers.

For all children to have access to high-quality STEM experiences in preschool, their teachers need to be well-prepared in both content and pedagogy to lead high-quality STEM experiences in their classrooms. We must revamp early childhood program and teacher accreditation requirements to include preparation and continuing support in the STEM disciplines.

WHERE WE ARE

Current pre- and in-service education programs for early childhood educators do not prioritize preparing future or current educators to provide good instruction in the STEM disciplines. In addition, most student teaching and other field experiences associated with early childhood professional preparation programs do not explicitly allocate time for meaningful experiences involving the STEM disciplines.

These issues are interconnected, and are the result of deficiencies in program and staff accreditation, teacher preparation, and in-service professional development. Accreditation procedures for preschools and preschool staff do not emphasize STEM preparation or coursework. As a result, many early childhood teachers leave their professional preparation programs with inadequate background and expertise in STEM content and teaching methods; this then has a negative impact on the pre-service early childhood teachers who apprentice as student teachers in their classrooms. Furthermore, the typically low salaries of early childhood teachers and other caregivers make it financially prohibitive for them to seek additional education to learn more about early childhood STEM content and pedagogy.

WHERE WE WANT TO BE

Improved attention to STEM content and pedagogy in pre-service and in-service training will produce early childhood educators who understand the importance of STEM for young children, feel confident in STEM content areas, and provide higher-quality and more diverse STEM experiences to their students. Further, when early childhood accreditation requirements consistently include STEM training and professional development, it will provide incentive for teacher education programs to provide coursework and field experiences in STEM disciplines, and for teachers to seek these out.

STEPS TO GET US THERE

Develop infrastructure to provide STEM education for the existing early childhood workforce. The current workforce of early childhood teachers has limited preparation to provide good STEM instruction, so they need in-service support to develop their understanding while in the classroom. Current pockets of innovation in universities and other centers can provide leadership and viable models for scaling in-service STEM professional development to large numbers of early childhood educators.

- Identifying current effective STEM professional development programs that have the potential of scaling.
- Investing in the development of resources, including training materials and online modules, associated with those programs so that they can be used widely.
- Identifying and developing a cadre of early childhood STEM coaches who can serve as professional development leaders and mentors for other early childhood teachers, and incentivizing, through widely available grants and stipends, participation in such professional development programs.
- Providing opportunities for administrators and school leaders to learn what high-quality STEM looks like in early childhood. Support from school leadership increases the likelihood that teachers will be given time and support to engage thoughtfully with the STEM professional development they receive.

Review and improve state and national accreditation standards for inclusion of STEM disciplines. To make thoughtful recommendations about how to incorporate STEM concerns into the accreditation standards, a thorough review of the standards is needed. At least three sets of interrelated accreditation standards should be considered:

- **Accreditation for early childhood teacher-training programs.** For teachers to have sufficient training in STEM disciplines, their training programs must offer and require relevant coursework. A 2005 examination of required coursework for early childhood teachers in New Jersey found that almost none offered targeted mathematics or science work. To understand the current landscape of professional expectations across the country, the field needs more current information.
- **Credentialing for early childhood teachers.** The 2009 National Association for the Education of Young Children (NAEYC) position statement on early childhood professional preparation mentions mathematics and science as content areas that teachers should be prepared to teach. However, most early childhood programs do not dedicate sufficient time to preparation in the STEM disciplines. More teacher preparation time must be devoted to STEM topics.
- **Accreditation for preschool programs.** Requirements for accreditation of preschool programs should affirm that teachers have sufficient credentials and/or background in STEM as a prerequisite for employment. They should also emphasize sufficient ongoing support and staff training in STEM disciplines for teachers.

Improvements in accreditation and certification standards will promote change best if they happen in collaboration with each other and in step with appropriate and new STEM content and pedagogy course offerings at universities and other teacher preparation programs.

Create early childhood teacher education fellowships to increase the number of STEM-focused early childhood teacher educators. To increase the number of early childhood teachers who are well prepared to teach STEM topics, more early teacher educators who specialize in STEM are needed. This can be accomplished by establishing grants or fellowships that support masters and doctoral students to pursue degrees with an emphasis on early childhood STEM education, and to pursue careers as teacher education faculty. Fields of faculty specialization should include mathematics, science, and engineering, and expertise on appropriate uses of technology in an early childhood setting.

Engage universities to develop undergraduate and graduate specializations in early childhood STEM education. In addition to including more STEM content in all early childhood teachers' coursework, universities should be encouraged to develop early childhood STEM specializations within their graduate and undergraduate education programs. These specializations can be modeled on existing literacy specializations, and should involve intensive coursework on high-quality STEM content and methods, pedagogy around engaging young children in STEM disciplines, and field experiences with experienced mentor teachers who have demonstrated competence and interest in developing high-quality STEM experiences for their students. Planning grants to support program development can seed the establishment of such programs.

Plan for long-term commitment to high-quality STEM education for teachers. The problems with teachers' lack of preparation to teach STEM in early childhood are deep-seated and will require a sustained, long-term effort to enact real change. We must maintain focus on increasing the number of preschool teachers who are well-prepared and confident in their STEM teaching.

These long-term goals include:

- Articulating a pre-service to in-service pathway for teacher development and support in STEM. If pre-service faculty can count on teachers receiving ongoing support in their STEM teaching, they will feel less pressure to cover the breadth of all STEM content and methods, and can focus instead on rich, deep engagement with the most important foundational STEM content and pedagogy. Similarly, if in-service professional development providers can assume certain background knowledge from teachers, they can provide ongoing support to build on this knowledge and strengthen teachers' competence and confidence as they become more experienced.
- Developing more and better pre-service coursework and in-service professional development offerings, including syllabi and textbooks.
- Training more STEM coaches, professional development providers, and faculty to provide pre- and in-service support for teachers.
- Developing high-quality tools to support STEM faculty and coaches, and ensuring that they are widely and readily available. These tools should be updated regularly to reflect current research.

RECOMMENDATION

3

Parents and Families

Establish initiatives, resources, and supports that promote parents' and families' involvement and engagement in their young children's STEM education.

Parents play a key role in shaping children's early experiences in STEM at home, and in creating demand for high-quality STEM education in their children's early childhood settings. Too often, parents lack the knowledge or confidence to support children's early STEM education. We need robust supports that build adult and child self-efficacy around STEM, inspire family involvement in STEM at home, convey the importance of STEM experiences in early childhood, and empower families to expect and advocate for high-quality STEM education in their children's schools.

WHERE WE ARE

Parents are children's first teachers, and their expectations for their children are powerful predictors of children's future interest and success in STEM fields. However, when they do not realize or trust their own power in shaping their children's interest and learning about STEM topics, they lose valuable opportunities. Many parents think of mathematics, science, engineering, and technology as "school topics," and not ones they can help their children develop at home through play and inquiry. They may not realize that activities their children do every day, such as helping with laundry or taking a bath, can be ideal moments to encourage thinking about STEM topics. They may avoid engaging in STEM experiences with their children because they themselves have STEM anxiety. Or, they may lack awareness about the importance of STEM experiences in early childhood. Moreover, they often do not know how to advocate for high-quality STEM learning opportunities in their children's schools.

WHERE WE WANT TO BE

Informed parents can be powerful agents in changing societal attitudes, beliefs, and practices around STEM in early childhood. All parents, including those from linguistically- and culturally-diverse communities, should have knowledge of and access to many simple ways to build important STEM foundations in their everyday interactions with their children, and feel confident in doing so. Further, they should feel knowledgeable and empowered enough to advocate for high-quality STEM experiences for their children in school.

STEPS TO GET US THERE

Get better information to parents about their own role in early STEM learning. Many parents will benefit from information about and exemplars that show how they can be active, engaged STEM role models and teachers for their children every day. Organizations that support parents of young children, such as the National Parent Teacher Association or the American Academy of Pediatrics, can play important roles in educating parents about STEM. Working with early childhood researchers and expert practitioners, they can disseminate important information and ideas for parental supports around STEM, such as:

- Suggesting ways to incorporate STEM learning opportunities in everyday situations, such as mealtime, bath-time, commutes, and so on.
- Providing ideas for how parents can help their children learn and be excited about STEM topics, and helping to disseminate developmentally appropriate STEM activities for children.
- Dispelling the myth that STEM abilities are innate, as well as other misconceptions, such as that math is hard or that engineering is job training.
- Educating parents about how their own implicit STEM stereotypes (*girls aren't as good at math as boys*) or anxieties (*I'm not a math person*) may be inadvertently transmitted to children, and providing supports for counteracting this.
- Communicating appropriate expectations for the development of children's early STEM learning.

Develop early STEM community engagement and education opportunities that focus on parents and families. For parents to change their attitudes and expectations about STEM in early childhood, they need good, concise information about what it is and isn't (e.g. it *is* expressing curiosity and making observations about natural phenomena; it *isn't* teaching rote facts or technical vocabulary), why it matters, and how they can play a role in developing their children's curiosity about STEM.

These sorts of messages often only reach a subset of parents (highly-educated, English-speaking parents, for example), and are presented in inaccessible or esoteric ways. Parents should have access to information from a wide range of community sources. For example:

Mathematics in everyday activities

A trip to the playground provides abundant opportunities for playful mathematics learning. For example, children can be enticed to think and talk about various measurement concepts, including describing and comparing lengths, heights, distances, and speeds. *Which slide is **longer**? Can you swing as **high** as the branches? Which tree is **closest** to us? Your hole is so **deep**! Look how **fast** that squirrel runs!* There are also myriad opportunities to count all sorts of things—pushes of a swing, rungs on the monkey bar, steps on the ladder, clouds in the sky, jump rope jumps, and seconds it takes to run around blacktop. A wonderful way to promote productive math play at the playground is to bring tools like stopwatches (or the timer on a phone) and tape measures to incorporate into children's activities. Children also have opportunities to explore and enact geometric and spatial concepts on the playground, as they discover shapes in the environment (e.g., the rungs of the monkey bars make rectangles, and the tire swing is a circle) and as they go ***across*** monkey bars, ***up*** ladders, ***down*** slides, ***through*** tunnels, and ***under*** jungle gyms. Children come to learn and understand these words and concepts if adults use this language to describe what children are doing as they play. Creating obstacle courses together and describing each step is an engaging way to introduce and practice new words and ideas.

- **Early childhood providers** can send "STEM outreach" newsletters home to parents, with information on what children are doing at school and how parents can continue the learning at home, and requests that parents share STEM ideas and activities from home to inform school experiences.
- **Doctors and dentists** can have "STEM While You're Waiting" brochures with ideas and activities for parents and children in their waiting rooms.
- **Community outreach organizations** can develop text message-of-the-day campaigns that provide very brief daily STEM activities for young children.
- **Advocacy organizations** can develop public service announcements about early childhood STEM to display on public transportation
- **Informal education institutions**, such as museums, libraries, and nature centers, can educate parents about STEM topics and inspire them to seek out STEM interactions with and for their children.

Each of these outreach efforts should be communicated in English and other languages, specific to local contexts.

Empower parents to advocate for high-quality STEM in their children's early childhood settings. Parents and families need to know what they can and should expect from their children's STEM education in school. They need examples and information about what high-quality preschool STEM looks like, and what they can expect from teachers and administrators regarding STEM education. Importantly, they also need strategies for effective ways to demand more and better STEM experiences if they are not satisfied. Websites and tools should be disseminated with tips to help parents communicate effectively with schools (and vice versa) about their expectations around STEM in the classroom. Moreover, developers should view parents as an audience when creating early childhood STEM resources. This might include short activities that parents can do with their children or parent letters explaining the goals of projects to parents.

Science in everyday activities

A sunny day provides opportunities for open and guided shadow play that supports learning about the nature and behavior of light. When children notice and make shadow shapes and chase their shadows, adults can bring out chalk to trace the shadow outlines and invite children to explore what is happening through their play. Can you find a way to hide your shadow? Can you make it large or small? How did your shadow change from morning to afternoon? Shadow hunts draw children's attention to light sources and the shadows that are created. Where are there shadows? What causes them? Are they sharp or fuzzy? I wonder why? Children can also use flashlights and desk lamps for indoor shadow play that provides opportunities to see what happens to the shadow of an object when the object or the light source is moved. How can you make the shadow larger? Smaller? Change its shape? What happens when we can see through the object? Children can also explore and apply these ideas in creative play by using a box and light source as a shadow theatre and making shadow puppets and objects on sticks. A guiding adult can also highlight mathematical ideas of shape, size, and distance as parts of these explorations.

RECOMMENDATION

4

Classroom Resources

Make high-quality early STEM resources and implementation guidance available to practitioners.

Early childhood educators too frequently lack access to high-quality STEM education resources, lack guidance about what makes STEM resources high quality, and lack support for using available resources effectively. Educators need clear and concise information about what constitutes a high-quality STEM resource, and they need access to and support for implementing existing and newly-developed high-quality resources.

WHERE WE ARE

Early childhood educators have more access to high-quality mathematics resources and supports (and to a lesser extent, science) than they do for engineering, but these resources are often hard to disentangle from lower-quality STEM resources that may be readily available on the Internet or elsewhere. Teachers often resort to cobbling together STEM activities and lessons from un-vetted resources such as Pinterest, making it nearly impossible to construct cohesive projects or units, let alone a full-year curriculum. They also do not receive adequate training on resources they do use.

WHERE WE WANT TO BE

High-quality instructional materials play an important role in all grades in promoting effective STEM instruction. Such materials are particularly important in early childhood programs, given the limited background most early childhood teachers have in STEM. Students will benefit if teachers are able to devote more time and energy to deepening their learning about how young children learn STEM topics and how to use high-quality STEM instructional resources productively, rather than trying to construct those resources themselves. For this to happen, teachers need user-friendly, research-based STEM resources, and strategies and support for their effective implementation.

STEPS TO GET US THERE

Articulate a vision for high-quality STEM resources. High-quality, early childhood STEM materials share a set definable properties. Articulating these properties will give teachers and school administrators (as well as parents and policy-makers) guidance for identifying good STEM resources. We propose the following properties, or heuristics, as a starting point in identifying high-quality STEM resources:

1. **Content and methods are developmentally appropriate.** Real rigor in preschool involves challenging children to think deeply within active, interesting experiences, using content they are capable of engaging with. Given the right guidance and thoughtful input from their teachers, children will learn mathematics, science, and engineering through active play, inquiry, and discovery.

2. **Context is connected to children's everyday lives.** Children learn best when new concepts are experienced in a meaningful context. For example, children learn more engineering through developing solutions for problems they care about, such as building the fastest ramp for their favorite cars, than through working on topics or problems that have no meaning in their lives.

3. **Materials focus on big ideas of math, science, and engineering.** Big ideas are key concepts and skills that are central to disciplinary learning, consistent with children's thinking, and generative of future learning. Activities should help children connect their experiences with the big ideas that foster long-term disciplinary understanding, and challenge their misconceptions; they should not engage children in surface-level experiences, such as "magic trick" science. (See pages 30-31 for examples of disciplinary big ideas.)

4. **Materials are educative for educators.** High-quality STEM resources support teachers' understanding of the big ideas behind the activities and use of materials. They also include information and advice for teachers about the most effective ways to use the materials.

5. **Materials emphasize opportunities for children's active engagement in STEM practices.** STEM in early childhood should emphasize teaching children how to engage in these disciplines, rather than race to teach specific content. A solid foundation in STEM practices will lay groundwork for children to learn STEM content more deeply later in their schooling.

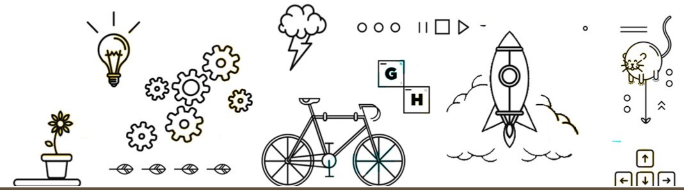
6. **Materials support children's sustained inquiry.** High-quality STEM work involves children observing and investigating concepts and content over time. Rather than isolated activities that do not allow children to engage deeply with the concepts involved, STEM materials should help educators develop intentional courses of inquiry that have a clear framework and progression.

7. **Materials make appropriate use of technology.** STEM resources that use technology well can be great equalizers in early childhood. Technology can help children communicate ideas they do not yet have words for, or record things they notice and reflect on them later. Technology used appropriately *promotes* discussion and collaboration between children; it does not squash or replace it.

Get high-quality resources and support into educators' hands. A strong infrastructure is needed in order to get high-quality resources into the hands of as many early childhood educators as possible. This involves helping school leaders understand that, just as they invest in curricula for their K-12 teachers, they must invest in high-quality instructional materials for preschool teachers. Equally importantly, it involves providing ample implementation support to help early childhood educators use the resources they receive most effectively. This includes support for how to use the materials with students with different cultural and linguistic backgrounds.

Develop new resources to fill current gaps. A variety of early childhood STEM teaching resources already exist, but more are needed, especially in engineering. While we want to get resources into the hands of teachers, poor quality resources and inadequate implementation support will undermine efforts to improve instruction. Creating high-quality resources takes time, and poor-quality products should not be rushed to market just to fill a need. Instead, funding should exist to develop instructional materials that meet the standards set for high-quality materials.

SAMPLE Big Ideas in STEM Disciplines



The tables below provide some foundational big ideas in science, engineering, and mathematics, alongside examples of how they might be operationalized in early childhood. These are *not* exhaustive lists of the STEM big ideas young children should encounter in these topics and disciplines; rather, they are meant to illustrate the kinds of thinking and engagement that are appropriate for children at this age.

ENGINEERING: Materials	Early Childhood Examples
Big Idea: *Materials have properties that can be explored and described.*	Sandpaper is “scratchy, rough, stiff, and brown” and felt is “fuzzy, soft, bendable, and green.” Materials can be sorted and compared based on their properties.
Big Idea: *The properties of a material determine whether it is a good or poor choice for a task.*	Based on your investigations of the materials, which ones will you use to build a strong bridge or a loud rattle? Why did you use felt to make your winter hat?
Big Idea: *A single problem can be solved using many different materials.*	Spoons can be made of different materials, such as wood, plastic, and metal. Let’s make a list of different materials we could use to make a bag.

ENGINEERING: Engineering Design	Early Childhood Examples
Big Idea: *Engineers use a multi-step process to solve problems.*	Whether designing scoops, sails, or noise-makers, children can follow the same engineering design process: “Explore, Create, Improve.”
Big Idea: *Engineers evaluate the design based on how well it meets the goal(s)*	Children test their scoops, sails, noise-makers, and other designs and reflect on the results. Children judge designs based on how they perform, not how they look.

SCIENCE: Structure and Function	Early Childhood Examples
Big Idea: *The shape and stability of an object or living thing is related to its properties and functions.*	Animals and objects with wings can fly; animals and objects without wings can’t fly. Round objects and objects with round wheels roll; objects that are *not* round or do not have round wheels do not roll.

SCIENCE: Cause and Effect	Early Childhood Examples
Big Idea: *Events have causes, sometimes simple, sometimes multifaceted.*	Rolling a ball down a ramp knocks over a block at the bottom. A pea seed grows into a pea plant when planted in soil, watered, and exposed to light.
Big Idea: *Scientists investigate and explain the causes of events.*	What happens to the block when we change the height of the ramp or the size of the ball? How can we find out what happens if a plant doesn't get sun or water?

SCIENCE: Stability and Change	Early Childhood Examples
Big Idea: *Some things stay the same, while other things change.*	Plants grow and people grow, but block buildings do not.
Big Idea: *Things may change slowly or rapidly.*	What grows more quickly: you or our pea plant? How can we find out?

MATHEMATICS: Patterns	Early Childhood Examples
Big Idea: *Patterns are sequences (repeating or growing) governed by a rule; they exist both in the world and in mathematics.*	Dots on a ladybug or posts of a fence Adding 1 to any number gives you the next number.
Big Idea: *Identifying the rule of a pattern brings predictability and allows one to make generalizations.*	After lunch comes recess. If we keep counting people's feet, it will always be 2 more.
Big Idea: *The same pattern structure can be found in many different forms.*	Big ball, small ball; big ball, small ball; big ball, small ball… OR snap, clap; snap, clap; snap, clap…

MATHEMATICS: Measurement	Early Childhood Examples
Big Idea: *Many different attributes can be measured, even when measuring a single object.*	A bucket has many measurable attributes, including height, weight, capacity, and circumference: What kind of "big" is it?
Big Idea: *All measurement, direct or indirect, involves a "fair" comparison.*	Weighing rocks on a pan balance (direct comparison) Using a length of string to measure tables in different rooms (indirect comparison) A "fair" comparison measures the same attribute. Units must be of equal size, with no gaps or overlaps.

RECOMMENDATION

5

Standards

Ensure that early learning and development standards explicitly address the STEM disciplines and align with K-12 standards.

State-level early learning standards and guidelines currently vary in their recognition of STEM disciplines as areas of focus for young children's learning, and in their alignment to K–12 standards in science, technology, engineering, and mathematics. Standards and guidelines influence teachers' and principals' priorities for their youngest students. If STEM is recognized and highlighted in early learning standards, it will bring increased attention and time to those areas in preschool. If the standards are well aligned with K–12 standards, it increases the likelihood that children's preschool experiences will prepare them for what they will be asked to do in kindergarten and beyond.

WHERE WE ARE

Since 2012, more than 40 states have developed or updated their standards or guidelines for young children. However, early learning standards vary from state to state in terms of the degree to which they address each of the STEM content areas. Currently, all 50 states include mathematics early learning standards, and nearly all states have some science standards. However, very few include engineering or technology standards, and only one state, Pennsylvania, explicitly recognizes STEM learning in its standards as a cohesive set of skills and dispositions for making sense of the world. Early learning standards for STEM are also not always aligned with K-12 standards for the corresponding disciplines.

WHERE WE WANT TO BE

High-quality, well-aligned standards can help guide teachers prioritize STEM in their classrooms and focus on the STEM content that is most appropriate and important for preschool learners. Teachers, school leaders, and decision makers will be more likely to prioritize STEM disciplines in early childhood when they understand how STEM experiences in preschool lay the foundation for later success in STEM fields.

STEPS TO GET US THERE

Identify guidelines for exemplary early learning standards in STEM. High-quality early childhood STEM standards will share a set of defining criteria, grounded in research and best practices in early childhood. We propose the following criteria as a starting point to develop exemplary early childhood STEM standards:

- **Discipline-specific:** Each discipline (science, technology, engineering, and mathematics) is addressed separately and the standards focus on the important content ("big ideas") of that discipline.
- **Includes STEM practices:** The standards explicitly recognize important habits of mind within each discipline, as well as the common practices across STEM disciplines.
- **Detailed:** Standards are specific enough that teachers and administrators know what children should know or be able to do.
- **Aligned:** Early learning standards are clearly aligned with kindergarten standards in each discipline.

Review existing early learning standards for existence and quality of STEM content and for alignment to K-12 standards. State early learning standards and guidelines vary widely along a variety of dimensions, including the emphasis they place on STEM disciplines, the specificity of their preschool benchmarks, and their alignment with state K-12 standards. For example, some states have mathematics and science as separate domains of learning for preschool, while others combine them into a more general category with other cognitive abilities. And, while almost no set of standards spans the range from Pre-K to 12th grade, several do provide direct alignment from their early learning standards to their state kindergarten standards (a few, namely Vermont and Washington, even align through 3rd grade). In contrast, other Pre-K standards are stand-alone documents. A careful review of each state's standards is needed to understand this variety, and to determine the quality of each state's STEM standards.

Draft a set of high-quality STEM early learning standards. Early childhood experts, researchers, policy-makers, and advocacy groups should work together to develop a set of rigorous and developmentally appropriate standards for STEM disciplines. These standards should build from the criteria suggested previously and incorporate the existing work already adopted in some states. For example, Massachusetts has developed preschool Science, Engineering, and Technology standards that align with the K-12 Next Generation Science Standards (NGSS). New York has adopted explicit technology standards for preschool. Maine has aligned the Common Core Standards for Mathematical Practice to precursor math practices for preschool. Arizona gives teachers "Indicators and Examples in the Context of Daily Routines, Activities, and Play" for each standard strand. Utah has transparent alignment to the Kindergarten Common Core State Standards and Utah's state science standards. Once developed, these new standards should be reviewed and updated regularly to reflect new research and current understanding of young children's engagement with STEM disciplines.

Advocate for states to adopt the new early childhood STEM standards. Once high-quality STEM standards are drafted, organizations such as the National Council of Teachers of Mathematics (NCTM), the National Science Teachers Association (NSTA), the Fred Rogers Center, and NAEYC, should educate policymakers about the new standards and encourage relevant state officials to update their state's standards to reflect the importance and urgency of including more and better STEM experiences in children's early schooling.

RECOMMENDATION

6

Research

Develop and support a research agenda that informs developmental trajectories, effective resources, and best practices in early childhood STEM education.

A firm research foundation is needed to guide policies and investments related to early childhood STEM education. Funding agencies should prioritize research that will fill current gaps in knowledge about science, technology, engineering, and mathematics teaching and learning in early childhood. This includes support for researcher-practitioner partnerships to help ensure that high-quality research addresses the realities of early childhood classrooms, and that the findings reach those who need it, namely teachers, administrators, curriculum developers, professional development providers, and pre-service teacher educators. Research findings can be made accessible to these audiences in forms such as curricula, professional development materials, and products that practitioners can use to enhance their work.

WHERE WE ARE

Currently, the amount of research on early childhood STEM varies greatly by discipline. As with many of the recommendations in this report, mathematics has led the way: we know a reasonable amount about mathematics learning trajectories in early childhood and about the importance of early childhood mathematics instruction to later school achievement, and we have begun to study effective practices for teaching mathematics to young children. In contrast, less research has focused on early childhood science, technology, or engineering, and even less has considered the STEM disciplines as a unified construct in early childhood. Furthermore, research and practice often do not intersect: practitioners do not know about the available research and its implications, and research findings, often done with children in lab settings, do not account for the messy, noisy reality of a preschool classroom.

WHERE WE WANT TO BE

More and better research is needed to guide the implementation of high-quality STEM education in early childhood classrooms. We also need more applied early STEM research: research conducted in authentic early childhood settings that focuses on the effectiveness of early STEM programs, and that attends to specific early STEM teaching and learning challenges. Such research will decrease the gap between research and practice and is more likely to influence early STEM teaching and learning practices.

STEPS TO GET US THERE

Conduct a comprehensive review of research on early childhood STEM. Before we develop a research agenda for early childhood STEM education, we need a more thorough understanding of the research that has already been done, its implications, and the new questions it generates. Funding should be devoted to generating syntheses of available research for each discipline and for STEM as a whole. These syntheses can inform the work we suggest in the other recommendations in this report, and they should be updated as new research is completed and disseminated.

Propose a multi-pronged research agenda to help private and government agencies determine funding priorities. We should construct a research agenda that prioritizes areas or topics where we know little about teaching and learning. This agenda should include shorter-term goals (research that builds directly on current work or is urgently needed to move the field forward) and longer-term goals (such as longitudinal research). Across this agenda, research should be done including students from varying cultural and linguistic backgrounds. Below are some sample areas that we propose for consideration as funding priorities for research in the STEM disciplines:

Student learning

- What foundational concepts and practices should teachers focus on during preschool?
- How does, or might, children's STEM learning in K-12 build on their experiences and learning in preschool?
- What habits of mind and processes unite the STEM disciplines during preschool?
- What does effective early STEM education look like across varied educational settings such as classrooms, museums, and libraries?
- How do interaction and communication affect young children's learning and intellectual growth in the STEM disciplines?
- What uses of technology support young children's communication, collaboration, and social-emotional learning?

Teacher preparation and professional development

- How prepared are beginning early childhood teachers to teach STEM?
- What is needed in pre-service teacher education and in-service professional development to prepare and support the early childhood workforce effectively for STEM teaching?
- What do effective models look like for developing teachers' competence in each discipline?
- What stereotypes and anxieties do early childhood educators and students have about STEM? What interventions can counteract them?

Development and evaluation of resources

- Which resources show positive effects on student and/or teacher learning and attitudes toward STEM, and by what mechanisms?
- How to move interventions from small-scale success to large-scale implementation?

Create and sustain pathways that connect and support bidirectional influence between research and practice. We need research-practice partnerships to inform research spanning methods and goals, including laboratory studies, research on children in their home and neighborhood environments, classroom-based research, design and development studies, and implementation research. These partnerships may include developmental researchers, education researchers, parents, teachers, teacher educators, school leaders, curriculum developers, and/or professional development providers. Each of these groups brings unique skills and expertise to understanding and implementing best practices. Researchers and practitioners should construct and sustain easily-engaged mechanisms to exchange ideas and findings.

Provide funding incentives for research-practice partnerships. Funders can promote research-practice partnerships by making research funding in education contingent on such partnerships being secured during the proposal stage, and by requiring evidence of partnerships in their annual reports.

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