STEM in Early Childhood: Establishing a Culture of Inquiry with Young Children

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One of the most impactful and transformative practices early childhood teachers can engage in is the practice of inquiry. Inquiry requires educators to be both fully present and fully engaged in professional practice while adopting the mindset that the cycle of inquiry is never complete. In inquiry-based learning, the learner is at the center of the learning process. Discovery of new learning is encouraged through questioning, observing, exploration, and the sharing of ideas and reflection. In true inquiry, educators identify and investigate problems of practice, develop plans to improve, use evidence to have data-driven conversations, watch for evidence of progress, take action, and understand and reflect. Lifelong learning is not a new concept for educators, nor is the ability to reflect on practice. The exercise of inquiry, however, provides a framework to allow those behaviors to become more intentionally focused. The goal of teacher inquiry is a transformative educational practice. Cochran-Smith and Deemers (2010) sum up the practice of teacher inquiry, remarking that "it is a powerful way for teachers and teacher educators to understand the complexities of teaching and learning, construct rich learning opportunities for all students, interrogate their own assumptions, and work for social justice" (p. 14).

There are many frameworks used in inquiry practice with all anchored in questioning and reflection. Educators engaging in inquiry should be transparent about assumptions and open to new ideas, feedback, and improvement. Adding collaboration with colleagues becomes a powerful and important component of inquiry. In a study that explored the results of teacher inquiry, teachers shared that the opportunity to engage with other teachers in the inquiry project gave them reassurance that they were not alone in the challenges and questions they had about improving student learning (Jao & McDougall, 2015).

The process of inquiry is also a powerful learning tool for young children. Engagement with inquiry in both teaching and learning transforms a classroom into a community of learners. Inquiry for young children can also be transformative as students explore ideas and materials, access prior knowledge, and construct new meaning and learning. The use of an inquiry approach is especially suited to Science, Technology, Engineering, and Mathematics or STEM topics in early childhood. Young children, who are both naturally curious about how things work and inherently trial and error learners, can be guided in the processes of inquiry in STEM topics to enhance and deepen learning.

Why Use Inquiry in Early Learning Environments?

Planning for inquiry learning by exploring STEM concepts can have long lasting benefits for young children. With a clearly documented need for greater access to technology and career preparation in STEM fields for women and students of color, early exposure to STEM is a wise investment of instructional time. A summary of research on early math learning found that effective math instruction "can enhance later learning and narrow achievement gaps" (National Science Foundation, 2018, p.1). In another study completed at Sultan Idris Education University in Malaysia (Binti & Siti, 2017), researchers studied the effects of using a play and inquiry-based learning tool to teach preschoolers numeracy concepts. The children participated in a series of lessons where they had the opportunity to question, solve real life problems, play with ideas, and reflect on their learning. They discovered that children were not only able to master numeracy concepts, but that their motivation for learning also improved.

Using knowledge about the benefits of inquiry, classroom teachers can simultaneously engage in their own inquiry cycles to improve their professional practice while creating STEM learning

such complex concepts. In fact, engagement with STEM concepts results in meaningful educational experiences for young children. As Sarama et al. (2018) point out, "young children are curious, inclined to explore, and eager to understand and make sense of their world" (p. 2). These characteristics make preschool and early primary students well suited for inquiry-based STEM learning. When STEM is taught using an inquiry model, the process is both integrated and collaborative, which nurtures multiple areas of children's development, including literacy and social competencies. Students are encouraged to ask questions, explore materials, use tools, and communicate their ideas as they experience the world around them, exercises which transcend learning within the content areas, helping children develop their understanding of both "content (what to learn) and processes (how to learn)" (Linder & Eckhoff, 2020, p. 28).

opportunities in early learning classrooms. Modeling the inquiry process for young learners creates a culture of inquiry-based learning, and students can benefit from the same mindset of continuous improvement, questioning, and reflection as they explore and investigate while learning STEM concepts. The purpose of this article is to explore some ways in which teachers can use inquiry for young children and for themselves with STEM experiences to promote a culture of classroom inquiry and improve learning outcomes for their students.

Creating a Culture of Inquiry with STEM

Teaching young children to engage in inquiry, particularly in the areas of science and math, can nurture powerful learning and social-emotional connections. Our university offers a course on STEAM (Science, Technology, Engineering, Art and Math) teaching for preschool and early elementary. In this course, we emphasize inquiry as an essential approach to STEM (with the addition of ART) for multiple reasons. One of these is the critical nature and need for the content. Mastery of STEM content is certainly important for children growing up in a technologically based society. More important, however, are the skills that engagement with STEM can nurture, such as problem solving, critical thinking, and collaboration. Ultimately, these are the skills our 21st century students will need to thrive when they leave the classroom, and current achievement data in math and science point to a need for a greater emphasis on instruction in these areas (National Science Foundation, 2018).

On occasion, our preservice students have expressed reservations about teaching STEM to our youngest of learners. They wonder if they should wait until children are a little older to introduce

Getting Started with STEM Inquiry: Learning Standards

The process of beginning inquiry teaching can be intimidating for teachers. Research supports the idea that teachers often feel unprepared to plan and deliver these experiences (National Science Foundation, 2018). One common concern is how an inquiry approach to teaching and learning STEM fits into a standards-based early learning framework. In our experience, inquiry learning with young children fits very well within early learning standards, although the process of connecting standards to learning is somewhat different than teachers typically engage in. Often, teachers examine the standards for learning and devise ways to teach children what they need to know. When using inquiry approaches with children, teachers observe and document what children say and do, and identify how children's emerging knowledge fits within early learning standards. This, of course, does not mean teachers cannot plan on helping children acquire the learning goals established for young children, but it does require careful observation, reflection and strategic planning to get there because the process is more open-ended, and child directed. Similarly, it is not necessary to neglect ongoing assessment of children's learning during inquiry lessons or units; in fact, the documentation associated with inquiry learning in early childhood, which can include dictation, images, artwork, video, and more, provide excellent evidence of children's learning. These pieces can be collected, assessed, added to portfolios and shared with families to display the inquiry process and progress in what is called STEAM learning, the integration of the arts into STEM. The knowledge gleaned by teachers from such pieces can also be used to plan further instruction for young children that will take them to the next level of learning.

STEM inquiry is also a naturally differentiated learning experience, with unique benefits for students with disabilities and students who are learning English. The process of inquiry makes room for students from all backgrounds and with a wide variety of skills to ask and answer the questions about a specific topic that are personally meaningful, and to construct the answers that build upon their current levels of understanding. We find the addition of art concepts to the STEM paradigm, STEAM, provides an especially helpful vehicle for students to express their learning. For students who may need accommodations or modifications, adding an art component can provide a means for expression of understanding outside of the constraints of typical written or verbal assessments.

The Cycle of Inquiry

The process of STEM inquiry can take a variety of forms and names, but the essence of the process stays the same and involves questioning, investigation, and reflection. The following are common steps in the inquiry process for both children and adults.

1. Ask: For ***teachers***, inquiry begins with questions about improving teaching and learning. A teacher may start with a question for a STEM unit. They may ask themselves questions such as: "What are the needs and abilities of the children in my care?" or "What do they children seem particularly interested in right now?" or "What are some skills and knowledge that would be especially useful to the children in my class right now?"

a. For young ***children***, inquiry also begins with asking or pondering questions about what they experience or observe in their environment. If needed, teachers prompt students with open ended questions and ask "What if we…" or "I wonder how …" until children begin to ask their own questions. McTighe and Wiggins (2013) provide a rationale for engaging in questioning as part of creating a culture of inquiry in classrooms: "The use of questions signals to students that inquiry is the goal of learning in your class and makes it more likely that a unit of study will be intellectually engaging" (p. 22). Young children view questions as an invitation to explore, uncover, and experiment with ideas.

2. Investigate: During the investigate portion of an inquiry cycle, the learner and teacher practitioner experience self-motivating opportunities to explore. ***Teachers*** explore the alignment between teaching, the environment, and the conditions for motivation of learning and exploration. Teachers watch children play, discuss, and explore materials, noting their thinking, ideas, and learning processes. Teachers gather data and make observations, which can allow them to decide next steps in the learning process. They also provide materials and experiences related to the STEM concept being explored that will allow children to investigate and explore the topic in their own cycle of inquiry. ***Children***, in this stage, use these to make meaning from their own set of perceptions, interests, and begin to connect new learnings with previous knowledge about the topic. As children investigate, they should be encouraged to think out loud. This helps them process new learning, communicate with peers, collaborate, and also helps the teacher by generating key observation data on the inquiry and learning process.

3. Create: In this cycle of inquiry, both teacher and students begin to construct new ideas based on the investigative portion of the cycle. A joint study between the University of Winnipeg and Winnipeg School Division (Betts, et. al, 2017) observed classroom teachers using inquiry in mathematics and found that inquiry not only triggered the natural curiosity and creative thinking of students but also the openness to create new meaning, thereby motivating students who may otherwise disengage in math. A ***teacher*** might engage young children to activate additional learning by providing new materials or tools, and pose questions such ask, "What are you noticing?" or "What do you think that means?" Teachers can watch and make note of learning that is happening, and what conditions promote learning, both for individual children and the group as a whole. ***Children*** can begin to represent their ideas and learning through words, pictures, and the arts.

4. Discuss: Successful inquiry includes collaboration. For both teachers and children, the practice of sharing ideas, data observations, assumptions, and new learnings is an important part of making meaning out of the inquiry process. ***Teachers*** can collaborate with colleagues about what they are observing in student behavior, motivation, brainstorm ideas, and address common assumptions. The teacher might encourage this same process with young children during the lesson by saying, "Tell us what you are noticing…." ***Children*** play and work in pairs and groups and discuss their ideas, observations, and conclusions, sometimes with prompting from the teacher. When young children collaboratively exchange ideas about STEM concepts as part of the inquiry process, they are also targeting key developmental growth areas, especially social- emotional and communicative learning.

5. Reflect: For both teacher and children, reflection as a part of inquiry invites the opportunity to not only look back, but also to look forward as new ideas merge with previous knowledge. For ***teachers***, reflection can be done through journaling or through conversations with colleagues. Reflection propels teachers to adapt and expand their lessons, engagement strategies, the learning environment, and curriculum. ***Children*** can reflect verbally with teachers and classmates, a process which can be facilitated through the review of artifacts created through the learning process, such as video, art, pictures, or stories. Foley and Green (2015) describe several skills to develop as part of young children's reflecting, including remembering, explaining, translating, sharing and revisiting. For example, the teacher can encourage reflection with young children through conversation and questions such as, "Let's look back at what you already know about…" and "What did you learn today?", and then dictate children's responses. These types of activities can be motivating for children as they see discover their own growth between previous knowledge and new learning and meaning.

Sink and Float Experiences: An Inquiry Cycle for Teachers and Children

The following table summarizes both student and teacher actions in this simple inquiry practice framework using a specific STEM lesson from an early childhood setting. The scenarios are based on the topic of sink and float, which was chosen because it is appropriate for a wide variety of age groups, from older toddlers to early elementary. It relies on common experiences and easily accessible materials in the early childhood classroom.

Table 1 Summary of Teacher's and Children's Inquiry Steps for Sink and Float

Inquiry Step	Teacher Action	Student Action
Ask		
The teacher asks questions about professional practice to improve children's learning and motivation. The teacher may hypothesize and address any assumptions about the question. *The children ask and discuss questions related to an observation or topic of interest.*	A teacher may ask: how can I motivate and develop student interest in understanding the properties of water and what makes items sink or float?	Children may notice natural phenomena (the Lego sank but the ball floated in the water table) and ask: what makes things float and others sink? They may make some predictions or hypothesize.
Investigate		
The teacher observes and gathers data about children's learning. The teacher may revisit assumptions about what children know or need to learn. *The children explore materials and engage in trial and error learning related to the specific unit or lesson.*	A teacher takes notes and observes student behavior, communication, and interactions while at the water table. She may provide other areas to explore water and items to test.	Students practice placing items in water. They observe which items float or sink and what makes them different including size, position, weight, kind, etc.
Create		
The teacher analyzes notes and data to challenge and refine assumptions about and plans for student learning and motivation. *The children use pictures, graphs, video, or other representations to document, sort and chart new learning. Guided by teacher questioning, they create new learning by discovering what they were surprised by in the learning process.*	Teacher documents children's explorations and assesses new learnings that surface. Notes are used to examine patterns in learning and behavior among students, as well are areas of misunderstanding. Teacher creates a plan for additional related questions or activities.	Children begin examining their ideas about things that float and sink. They create new ideas about why some things float and others sink based on their observations and begin to create new ideas. They generate hypotheses about what makes items sink and float and represent their understanding through graphing, sorting, and depicting ideas though words, pictures, and actions.
Discuss		
The teacher collaborates with colleagues to share and test ideas, assumptions, and new learning. *The children collaborate with peers to share and test ideas and new learnings about the unit or lesson.*	The teacher collaborates with colleagues to share observation notes, ideas, and new learnings about motivation and student interest in the sink and float activity.	Students share their ideas with peers and teachers and discuss their creations. For example, did they think the ball would float or sink? What about the pumpkin? What do the items that sink and float have in common? They may revisit assumptions, predictions, and new learnings. They may formulate new questions why items float and sink.

Inquiry Step	Teacher Action	Student Action
Reflect		
The teacher revisits initial inquiry questions. They may develop new questions for inquiry and reflect on any changes or adjustments needed to the classroom environment, lesson, or unit. *The children reflect on their initial questions about the unit or lesson though sharing out loud and re-viewing the learning process. They acknowledge new learning, and they may ask new questions.*	The teacher will revisit the initial question posed at the start of sink and float lesson. What are the new learnings? Based on the observational data, what would I do differently? How can I improve learning and motivation? What environmental conditions encouraged discovery and engagement in this lesson? How can I continue to capture that for further lessons?	Students would revisit the initial question posed at the start of inquiry about things that float and sink. They reflect on the learning process and articulate their new understanding about why items float or sink. They may be guided to ask new questions about objects that float and sink.

Resources

Teachers interested in developing a culture of inquiry through STEM instruction may want to start by exploring books and web-based resources created to support inquiry learning for teachers and young children. The web links in Figure 1 might be a good place to start:

Figure 1. Suggested Web-based Resources

The Smithsonian Science Education Center: https://ssec.si.edu/
This website is a unit of the Smithsonian dedicated to science reform for PreK - 8 students with a "curriculum is designed to meet the challenge of national and state standards by placing scientific inquiry at the core of science education programs." Numerous free curriculum resources and professional development materials are available.

STEMIE: Innovation for Inclusion in Education: https://stemie.fpg.unc.edu/
STEMIE was established by the Frank Porter Graham Institute at the University of North Carolina Chapel Hill to promote STEM learning for young children with disabilities. One notable feature is a Community page, where teachers can share and support each other with stories and ideas.

Teaching Great Lakes Science: https://www.michiganseagrant.org/lessons/teacher-tools/guided-inquiry-process/
Developed through the collaborative efforts of the University of Michigan and Michigan State University, this website was developed to provide support for teachers interested in learning about inquiry-based science teaching. Although the resources are focused more on students in older grades (grades 4 to 12), the content includes several helpful handouts explaining the process of inquiry which could be part of professional development or shared with parents.

Conclusion

The process of inquiry has benefits for young children as well as their teachers. Cheeseman (2009) discusses that the role of the teacher within the process of inquiry is to observe, listen, interact, and probe the children's thinking by encouraging them to share explanations and discoveries in order to promote continuous learning. Capturing their natural curiosity, STEM inquiry lessons can be collaborative, data-driven, and reflective for young children, allowing teachers to promote learning for diverse groups of young children as well as improve their professional practice. Whatever the STEM topic, presenting an inquiry experience to children, while at the same time teachers use inquiry tools for planning and modifying the learning experience as it unfolds, has the potential to result in a positive learning experience for all.

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