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Mixing it Up: Exploring Fizzical-Science through Play

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ABSTRACT

Young children have many opportunities to investigate physical science and chemistry concepts through play and exploration. While formal chemistry lessons are not within the scope of an early childhood classroom, there are ways to encourage children to engage in the processes of chemists. This article presents a framework for how to structure science lessons in the classroom that build upon children's theories and prior experiences. With a focus on mixing and how physical objects transform, we then present a variety of activities based on the framework, where children may deepen their knowledge of materials and interact through child-led explorations. We provide examples of how this can be done across many spaces (i.e. outdoors, the arts center) to honor the important work of play in early childhood classrooms and to highlight the many ways that children engage in science and theory-building throughout their day.

KEYWORDS

Science; play; chemistry; sensemaking; inquiry.

INTRODUCTION

Studies have explored children's images of scientists by asking children to draw a scientist (see Ferguson & Lezotte, 2020 for a review). Many children draw a mad scientist—someone with wild hair holding a beaker of glowing liquid that is bubbling or on the verge of explosion. The scientist is often in a lab wearing a lab coat and goggles or glasses. These images of scientists are pervasive in American media references- Doc Brown from Back to the Future, Doctor Frankenstein, and Rick Sanchez (Rick and Morty). Many books marketed towards children and teachers talk about science as magic, for example, *Science Magic Tricks for Kids: 50 Amazing Experiments that Explode, Change Color, Glow and More!* or *The Science Spell Book: 30 Enchanting Experiments for Kids*. This kind of marketing suggests that science is a mystical, mysterious process and that only the magician (i.e., the teacher) knows how to do science (with the sleight of hand). As adults, we understand that scientists often do not work in labs or create toxic potions; scientific work takes many forms. How do we communicate the work of science to young children? Children are often described as natural scientists or naturally curious, and yet, how children see scientists and even how teachers introduce science can shift children's ideas about what science is and who can do science. This article will present a framework and activities that honor children's curiosity and process of engaging in science, while also focusing on the practices and content that help children learn science.

Children as Scientists

We position our ideas about how children learn science from an inductive stance. Instead of science as a body of knowledge consisting of facts to memorize, we imagine science as a process children use to make sense of the world around them (Worth, 2010). From this perspective, children gather data from birth and come to early childhood spaces with background knowledge built upon a rich network of experiences (Fragkiadaki et al., 2023). Children go about the world trying to make sense of objects, animals, and people and how they fit within their environment. As infants, they explore objects using their senses to try to understand what objects are. As toddlers, they learn to act on objects—pushing and pulling, dropping, stacking. Children's sensemaking is evident in their play (Raven & Wenner, 2022). *How can I use this cup?* First, it is a cup holding juice, then part of a fairy house, and finally, it becomes the tuplex the unicorns use to capture their beslews (or some other imaginary creature)

When engaged in sensemaking, children often ask a lot of questions, like *How can I make it move? What happens if I…?* Children act on these questions—they squish the play dough, roll the ball down the slide, or drop the cup again (and again). Through these experiences, they develop working theories about the world. Worth (1999) describes the theories that children develop as being perceptually dominated, based on evidence, and tenacious. Children collect data about different aspects of their world, but the data is messy at best. Looks can be deceiving. For example, oftentimes large things sink, and small things float. There appears to be more liquid in the taller slender cup compared to the liquid in the shorter, rounder cup. Sometimes it rains when there are dark clouds, and sometimes it does not. Children's theories are based on what they see, and often children hold onto these theories despite someone telling them otherwise or being shown contrary evidence.

Children should be positioned as active meaning-makers and doers in early childhood classrooms (Larimore, 2020). The experiences that we provide for young children should be based on their previous experiences and build upon their current working theories. To support children as scientists, teachers should provide opportunities for children to do science (Dale Tunnicliffe & Gkouskou, 2020). It is not that children are naïve or poor researchers; rather, children first need many opportunities to test out their theories and explore. They need a lot of data in varied environments before they can generalize. They also need opportunities to hone their observation skills. Teachers can help children to focus attention on specific events and organize the data that they collect. Science can be taught through a process of conceptual change in which children reorganize their existing knowledge to understand scientific concepts and practices. This requires the active role of adults in driving children's initial curiosity from questions to active investigations.

We describe a framework for scientific inquiry below (described also in Beisly & Moffitt (2024) that involves three steps: play, exploration, and theory testing. While we present this framework as a cycle, we believe that classrooms should include all three steps in planning activities. However, children may move from play to exploration to play to exploration many times before theory-testing. It is often not a linear path. For example, children may engage in play in one area of the classroom but develop ideas that they explore in a different area of the classroom. The essential piece is exploration as a step between play and theory testing OR that children have ample time for play and exploration before theory testing. It is through play and exploration that children engage in the practices of science.

In play, children explore *What is this thing?* Play is a child-directed activity, where children actively make meaning of materials, concepts, or ideas using imagination and creativity (Nilsson et al., 2017). Science and sensemaking are evident in children's play when, for example, they create magic potions at the water table, build a home for a turtle in the block area, create shadows on the playground, or trace patterns on a steamy mirror. In this stage, children's imagination ignites their learning by encouraging them to dig in and explore. As Vygotsky (2004) suggested, ''imagination is based on our experiences, while creativity is a function of our ability to combine experiences'' (Abdo & Carulla, 2019, p. 9). The more children are provided with time to play that supports and develops their imagination, the more they will sharpen their abilities to view objects and people through different perspectives. The role of the teacher is to stand back and observe, closely listening in and attending to what theories children may be exploring through play.

In the second step, exploration, children explore the possibilities of materials. The teacher's role is to learn alongside the child—amplifying observations and focusing on language. As children play, they may be focused on what is happening, while the teacher can narrate or direct children's attention to specific aspects of what is happening. For example, the teacher can invite children to add water to their mud cakes or introduce props to create different potions. The focus of the exploration is still child-led; the teacher may introduce language to describe what is happening.

In the final stage, theory testing, children ask *What happens when I do [__] to [___]?* Much of children's theory-building comes from observation and experimentation with materials. Children move things, take things away, or add things. The teacher focuses students' attention on testable questions, and the teacher and students engage in activities to answer those inquiries. Children may be working in small groups exploring natural phenomena (Muimongkol, 2021). The teacher can support children as they use tools, collect and analyze data, and produce artifacts.

In the outdoor kitchen, the children might notice that the different consistencies of their mud cakes are related to adding water to the dirt. The teacher may provide different-sized pitchers to invite children to add water more consistently or introduce a different material to explore what happens to the cakes when sand and water are mixed. While the last stage includes testable questions, it is important to frame the theory testing as emerging from *children's* theories and ideas (Abdo & Carula, 2020). It is not time to introduce science experiments or activities with a strict sequence that children must follow.

In this article, we have decided to investigate children's sensemaking in chemistry through our activity framework. In part, it comes from rethinking the classic science experiment of combining baking soda and vinegar to create a volcano eruption. While it creates a memorable visual, young children do not understand what has happened. Instead of focusing on chemical reactions, we explore activities related to mixing and transformations, something that young children have had more direct experience with. By using children's theories about mixing as the foundation for activities or materials, teachers can support the science practices children will use later to investigate chemistry concepts. In the sections that follow, we will describe children's chemistry-related theories and present activities/materials throughout an early childhood classroom to support children's emergent science.

Sensemaking in Chemistry

Although children may not have much direct experience with chemistry in the sense of examining molecules or creating explosions, children do have ample experience with two key concepts that will build on formal science knowledge: transformations and mixing. In a general sense, chemists perceive the world as "composed of particles of various sizes that are in perpetual motion and that take part in processes of arrangement and rearrangement" (Abdo & Carulla, 2019, p. 544). To understand a change, children must understand the concept of transformation—that things may start as one thing and then change to another. Sometimes, two substances may be mixed and the product of their mixture is a substance with different characteristics from the original ingredients (Remountaki et al., 2024). Children are naturally drawn to mixing, and they use both the physical action of stirring and the result of this action to help them make sense of the world. Engaging in mixing play with young children involves providing opportunities for them to explore mix, smash, and take things apart as they experiment with cause and effect.

Children develop their working theories based on their experiences with materials. Many of their theories about transformations are based on perceptions (how something looks). Piaget et al. (1975) described this as the conservation of liquid or matter. For example, if children are shown two identical balls of clay, and they agree they are identical, children will focus on how the clay looks up until approximately age 7-8. If an experimenter is to squish one of the balls of clay or roll it out into a cylinder, the child under age 7 will typically say that the long roll of clay is bigger than the ball because it now takes up more space. Children are tenacious in their theory building because it looks bigger, so, why wouldn't it be bigger? Children need repeated experiences with materials and transformations before they will accept formal theories about the properties of matter.

One of the important, but difficult, things to understand about chemistry is that materials can cause different transformations. Sometimes things mix and sometimes they don't. Sometimes the result is a physical transformation and sometimes it looks the same but tastes different. For example, Panagiotaki and Ravanis (2014) explored children's ideas about what happens to sugar when it is added to water. Many children drew the sugar as visible dots within the water or as a clump, rather than drawing sugar dispersed within the water. In a similar study, Christiou (2005) described children's reasoning as agentic, i.e., attributing agentic qualities to items. In the case of sugar and water, the water or the person stirring the solution acts to dissolve the sugar. Children may also struggle to understand that some transformations are permanent and some are not. For example, we can (with some effort) separate the play dough or pebbles when they get mixed up but can't separate the drink mix from the water when it gets mixed.

Activities to Explore Transformations

The activities that follow are centered on the idea of mixing and the question of *what happens when I mix two things together.* We intentionally present activities teachers could observe or implement across various spaces inside and outside of the classroom. Our focus is providing experiences where children are active doers and sense makers. They produce the movement that creates the mixing or transformation. They can vary their actions to produce a mixture or transformation. This helps to create testable questions that children can answer. *If I do this a little bit, what happens? If I do this a lot, what happens?* Children can observe (or do) the transformation/mixing in real-time. Some transformations take time, and it can be difficult for children to have a sense of exactly what changed or what impact they have had. Activities to accompany each stage of the framework: play, exploration, and theory-testing are described below. Additional activities across the classroom areas can be seen in Table 1(below).

Mixing can be seen in child-directed play anywhere in (and outside of) the classroom. In the dramatic play center, children engage in mixing as they pretend to cook meals and prepare medicine for sick baby dolls or stuffed animals. The water table offers endless opportunities to discover which liquids and solids mix with water to create new substances and which do not. When it comes to color mixing, the light table can be used as a base to combine and then separate colors using color paddles, while at the art center, paints are mixed and transformed into new shades of color. Children can help mix ingredients to create play dough or slime and then mix in additional materials during sensory play to change the texture, color, or fluidity. Even on the playground, children engage in transforming play as they pick flowers and weeds and mix them into “salad” or smash chalk into powder and mix it with water to make paint. Finally, across centers, but perhaps in a math-designated center stocked with loose parts, children explore how to unmix—how to separate loose parts they have mixed during play and return them to their containers during center clean up.

Table 1.

Mixing Across the Classroom

Classroom Space	Play	Exploration	Theory-Testing
Dramatic Play	Making Medicines	Introducing measuring cups and recipe cards	Enacting a dramatic play scene with props—create a kitchen or compounding pharmacy
Art	Mixing paint colors	Mixing paint with glitter or other materials	What happens when we add water to paint? (spray bottles)
Sensory Table	How do solids mix–hiding or combining items in sand	Introducing mixing instruments—whisks & spoons	Which instrument mixes this particular material best? (How is form related to function) *introduce a new material to mix with – oil or slime
Outdoor	Making plant salads	Mixing dirt and water	How much water is needed to make mud?
Science Center (Focused on mixing solids)	Play with play dough (enjoy mixing different colors)	Mixing 2 materials: flour and sugar,	Creating a trail mix of different solid materials
Science Center (Focused on mixing liquids)	Using pipettes to move and mix water from one place to another	Mixing colored water; mixing sand and water	What happens when we mix a solid (sugar) and water? Does the wetter material flow over, sink into, or become absorbed by the drier base?

Moving into the exploration stage, teachers can provide new materials for mixing based on their observations of children's interests during free play opportunities. These materials should help children deepen their understanding of what is happening in the moment as they experiment with different mixing tools and with a variety of materials. Vegetable oil can be set out with watercolors for painting in the art center. Whisks can be provided for children to whip up bubbles from dish soap added to the water table. On the playground, buckets, trowels, and sieves can be stacked by a dirt pile or the sandbox for scooping, mixing, and separating dirt, sand, gravel, and other natural materials. In the dramatic play center, empty cans, paintbrushes, paint rollers, and colorful loose parts can be provided for children to pretend they are house painters mixing up imaginary paint colors.

Table 2.

Activities and Questions to Support Theory Testing

Children's Questions	Possible Materials
When does a hand, a whisk, a stick, or a paintbrush work the best for mixing? Does a stick or my fingers work better for mixing water and dirt on the playground? Does a whisk or a paintbrush work better for combining water and food coloring at the art center?	Outdoors – sticks, twigs, rocks, trowels, shovels, sieves, buckets Mixing colors – whisks, paintbrushes, pipettes, spoons, drink stirrers, funnels
Does the tool I use to mix change the outcome? What happens when I use a spoon instead of a paintbrush to mix my tempera paint? What happens when I mix fruit and yogurt with a blender instead of a spoon?	Provide a variety of tools for the same activity: Paint mixing – spoons, paintbrushes, popsicle sticks Cooking – spoons, forks, spatulas, whisks, blender, mixer
Does the type of materials (liquid/liquid, solid/solid, solid/liquid) I mix change the outcome?	Oil and water Water and liquid soap Play dough and powdered tempera Pom poms and popsicle sticks Marbles and paint
Is the mixture reversible?	Will the colors I mixed to create my painting separate back into the original colors? Mixing loose parts in the dramatic play center

By varying the tools and motions they use in exploration, children can evaluate the effectiveness of their mixing (Eggl & Schmid, 2022). As children are given access to new substances that can be combined with those they already have experience with, they can extend their knowledge about which solids mix with other solids, which liquids mix, and which solids and liquids can be successfully combined. Teachers can also support exploration by asking questions and making observations that help children gain a deeper understanding of what is happening as they mix and transform materials. They might comment on the speed, direction, or size of the mixing motion the child is using, ask the child what they notice about a solution they have mixed, or question why a child has chosen to use a certain tool for mixing.

Finally, children test their theories about mixing, searching for answers to specific questions that have arisen during the play and exploration stages. By making new tools and materials available for children to use to evaluate their ideas about how, why, and when things mix, teachers can support children's authentic learning about scientific concepts. As children test what happens when they combine materials repeatedly, varying their actions depending on the outcomes, they can determine whether their theories work in real life. They may ask questions and lead a variety of investigations (see Table 2).

CONCLUSION

Throughout this article, we have highlighted different materials and areas where chemistry (or mixing) can be integrated into existing classroom spaces and build upon children's interests. To conclude, we offer three ideas about how teachers can get started implementing these ideas: daydream, get messy, and be a scientist. *Daydream.* Teachers can give children space to pause and wonder. Children need time to think about things, imagine possibilities, and play with ideas. Sometimes, this may involve slowing down the pace, lingering with activities, or returning to ideas. Some children (and adults) naturally gaze out the window and imagine the possibilities, while some need prompting to get started. When teachers allow children to daydream, it lets them know it is okay to let ideas simmer.

Get Messy. Creativity fosters inevitable messiness. While many teachers are comfortable getting messy during art time, some may be uncomfortable when it comes to science. We encourage teachers to start with small messes or take science outside where it may be easier to clean. Messy here also means blurring boundaries and viewing topics holistically. Engaging in science does not mean breaking things down into discrete steps. Teachers can support children's learning by shifting from thinking about science as facts (like the parts of a plant) or topics (like the planets). Instead, teachers can focus on building a web of knowledge around bigger ideas like transformations or patterns.

Be a scientist. As children explore in the mud kitchen, teachers can explore themselves. Teachers can model the work of scientists by engaging in the practices of a scientist, such as persisting through trial and error. Teachers can share their own theories about the way the world works and test them, which moves them away from being the person in the room who knows the facts. It also allows teachers to become a co-conspirator in transformations, rather than a facilitator.

Chemistry concepts such as mixtures and transformations can be meaningful for young children when they are allowed to explore these concepts as investigators rather than as simply observers. There is no magic to science; every child can be a scientist in control of their own sensemaking through the cycle of play, exploration, and theory testing. By providing materials and opportunities for children to engage in mixing and transformation in every area of the classroom, teachers can empower children to find the answers to their chemistry-related questions. This positions children as active meaning-makers capitalizing on their curiosity in the moment, not waiting until a specified science time.

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