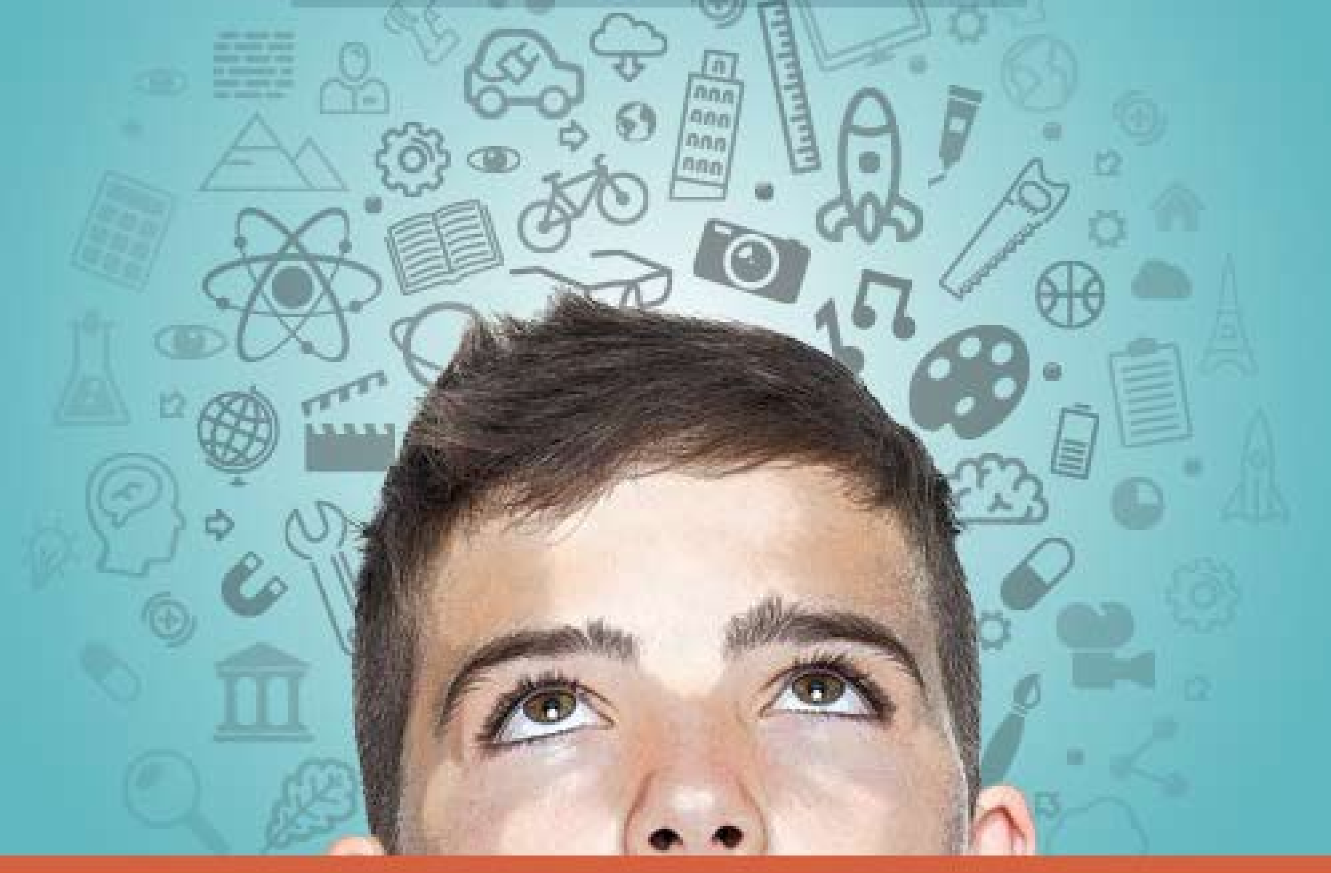
Wendy L. Ostroff

CULTIVATING CURIOSITY

in K–12 Classrooms



How to Promote and Sustain Deep Learning

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Introduction

How to Cultivate the Curiosity Classroom

What we want to see is the child in pursuit of knowledge, not knowledge in pursuit of the child.

—George Bernard Shaw,
The Quintessence of G.B.S.

Learning is what we humans do best. We learn throughout our lives by wondering and exploring, experiencing and playing. This book is about harnessing that ineffable drive in learners—the drive to know, understand, and engage in the world and its ideas. The philosopher Cicero defined curiosity as a love of knowledge without the lure of profit (1914), in other words, an intrinsic passion to know. Aristotle (1947) claimed that the desire to know is among the deepest human urges, and Francis Crick, the Nobel Prize–winning scientist who discovered the structure of DNA, was often described as childlike in his curiosity (Pincock, 2004).

Curiosity has been hailed as the major impetus behind cognitive development, education, and scientific discovery (Loewenstein, 1994).

It is the drive that brings learners to knowledge. Curiosity is about being aware and open, checking things out, experimenting, and interacting within one's surroundings. In a classroom grounded in curiosity, teachers have the unique opportunity of being able to mine students' deepest held wonder, making their attention natural and effortless, and allowing them to fully engage. Creating the conditions for curiosity in the classroom will allow us to achieve more authentic motivation from both teachers and students, leading to deeper learning.

It is no wonder that Curious George is one of the most beloved characters in children's literature. The little monkey who lives with the Man with the Yellow Hat wants to dig into each and every experience he comes across in order to explore and to experiment. And he often gets into trouble, especially because he is not limited by the things that are socially appropriate. He is free to do what he chooses, and is a monkey, after all, filled with all the monkeyshines we might expect. It is a good thing that Curious George has the Man with the Yellow Hat to save him from the tricky situations he gets himself into (to come by in a helicopter at just the right moment when George floats too high on a bunch of balloons, for instance). In the case of George, just as in the case of our students, playful curiosity plus scaffolding can transform into learning.

We don't need to teach our students to be curious—like George, they are already curious. (Though they may not be curious about what we want them to be curious about.) Maybe at this moment they are wondering how the clay feels in a kindergarten classroom readying for a project or wondering how to talk to a friend they have a crush on in a middle school science lab. Are there learning moments that a skilled guide can find at the intersection between what the students are curious about and the topics at hand? Can we take our students' interest in skateboarding on a half-pipe and direct it into an interest in physics or engineering? Can we use their interest in persuading their parents to get a pet and mold it into skills in persuasive writing or speaking? In this book, I will make the case that students' curiosity coupled with teachers' own wonder and experience can guide students into deeper inquiry.

Why Curiosity?

Being curious is an essential part of human consciousness, a joyful feature of a life well lived. But as recent research evidence shows, fostering curiosity holds a power that goes beyond merely feeling good. In fact, curiosity may be critical to student success in school. What are the mechanisms by which curiosity compels learning?

1. Curiosity Jump-Starts and Sustains Intrinsic Motivation, Allowing Deep Learning to Happen with Ease

When students are curious, teaching and learning are never a chore. Whereas motivation that comes from the outside (via incentives and rewards) tends to be fragile and short-lived, motivation that comes from inside ourselves, from the wellspring of genuine curiosity, is much like a wild fire: It cannot be tamed, it will take sudden new turns or directions, and it will seek fuel in whatever way it can. In a classroom based on students' curiosity, teachers needn't ever worry about motivation.

When children are allowed to follow their curiosity, they are more likely to stay on the path of exploration and insight. For example, a 1st grader's discovery of tadpoles in a marshy puddle in the play yard brings her immediate joy. That joy ignites the spark of curiosity, and she is then intrinsically motivated to further explore the puddle, since pleasure compels repetition. The girl may bring her classmates to see the puddle, or she may decide to look for tadpoles in other small ponds after school. In either case, she will seek to branch her experience outward. On each occasion that she returns to observe the tadpoles, she will pose questions and make hypotheses about them ("What do they eat?" or "How fast or far can they swim?"), with repeated observations guiding her mastery. The child will soon observe the tadpoles growing stubs of legs, and if she is allowed to continue to watch, she will witness the complex biological transformation of tadpoles becoming frogs. Her mastery of the topic, gained from experiential learning, will produce confidence. As this example illustrates, the movement into deep learning is fueled by curiosity and pleasure (Perry, 2001).

Research shows that any student, given the opportunity to be genuinely curious, will respond in precisely the same way. In one study, groups of 5th and 6th graders learned about endangered wolves or coal mining in class. The first group participated in a group discussion on the facts they had learned, while the second group entered into a debate about the controversies surrounding wolves becoming endangered or the strip mining of coal. In this case, as in other studies, the "seductive details" of the controversy sparked curiosity. The second group not only showed more enthusiasm during the project, they spent significantly more time working on it and were more likely to give up a recess period to learn more about the topic (Lowry & Johnson, 1981). The increased time spent engaging with these topics inevitably led students to delve more deeply into them, which helped students understand the complex concepts better and remember the content later (see also Garner, Brown, Sanders, & Menke, 1992).

2. Curiosity Releases Dopamine, Which Not Only Brings Pleasure but Also Improves Observation and Memory

The brain's desire and reward system (the producer of the neurotransmitter dopamine) is deeply embedded in our human development and evolution. Since social scientists believe that reward drives all behavior, and behavior creates evolutionary adaptation, the dopamine system has been critical in our evolution into the complex beings we are (Muller, 2014).

When students are curious and seek to satisfy their goals and desires, they get a hit of this pleasure-producing chemical. In one study on the effects of dopamine, people were given a list of trivia questions, like "Who was the president of the United States when Uncle Sam first got a beard?" or "What does the term 'dinosaur' actually mean?" and then asked how curious they were to learn each answer. They then were given brain scans while being presented with both the answers to the trivia questions and additional unrelated information. When the participants' curiosity was triggered, their brains released dopamine. Upon being tested afterwards, participants were much more likely to remember information on the topics they were curious about. In addition, when participants were in a curious state, they were also more likely to remember the paired, unrelated information. In other words, when we are curious, our brains' surge in dopamine causes us to take in and remember the entire landscape of experience and information more deeply. This is because dopamine makes the hippocampus (the part of the brain associated with long-term memory) function better (Gruber, Gelman, & Ranganath, 2014). Such research lends support to what nature writer John Burroughs observed nearly a century ago: "Knowledge without love does not stick; but if love comes first, knowledge is pretty sure to follow" (1919, p. 28).

3. Curious People Exhibit Enhanced Cognitive Skills

Curious students learn more and learn better. Current research shows that people who nurture the tendency to seek new information and experiences show lasting brain effects. In one study, researchers identified a group of 3-year-olds who were extra curious and followed their development throughout their childhood and school experiences. At 11 years of age, these children were earning significantly higher grades than their peers. They were superior readers and had IQ scores that averaged 12 points higher than their less curious counterparts (Raine, Reynolds, Venables, & Mednick, 2002).

In a related study at the other end of the lifespan, scientists discovered that older adults who were genetically predisposed to develop Alzheimer's disease, but who kept curiosity a daily part of their lives, warded off the disease for more than a decade. In particular, seeking out higher education, working in complex fields, playing music, avidly reading, and staying intellectually engaged created a recipe for keeping the brain effective and healthy (Vemuri et al., 2014).

The Curiosity Classroom Is Co-Created

When we as teachers recognize that we are partners with our students in life's long and complex journey, when we begin to treat them with the dignity and respect they deserve for simply being, then we are on the road to becoming worthy teachers. It is just that simple—and just that difficult.

—William Ayers, "The Mystery of Teaching,"
in *The Jossey-Bass Reader on Teaching*

Teachers play a critical role in helping students transform their curiosity into inquiry, by facilitating, focusing, challenging, and encouraging students in active engagement (Zion & Slezak, 2005). When a teacher guides students into new, related territory, expanding upon the interests of those students and branching them out, we call it scaffolding (Rogoff, 1990). Scaffolding supports those goals that the student can stretch to achieve with a bit of help but that he or she would be unable to reach alone (Vygotsky, 1934/1998). Again, supporting curious children is best achieved when teachers themselves are curious, when they are excited, involved, self-directed, and trying new things (Deci & Ryan, 1985; Engel, 2011; Ostroff, 2012). In that way, the curiosity classroom creates a culture of learning that emerges at the intersection of the students and the teacher.

Curiosity is cultivated within classroom walls as a shared endeavor involving both students and teachers as learners. It is a collaborative search beginning with ideas and questions from the lived situations of all members (Greene, 1995). Fostering curiosity involves listening to the myriad of voices and perspectives of the class community members and respecting each other enough to put oneself “out there.” Writer and teacher Parker Palmer (2003) has said that teaching is a daily exercise in vulnerability. Peers, too, take a risk by being present and prepared for the classroom setting based on curiosity. As one Brookline, Massachusetts, high school student put it, you don’t just get what you put into it, you get what the entire class puts into it (Kohn, 1993).

Curiosity is by nature subversive to the traditional, top-down classroom. When order in the classroom is desired most of all, curiosity can become a liability. After all, hunger and seeking are not obedient and tame. In a now-famous review of decades of psychological research, George Loewenstein (1994) discovered that curiosity was most associated with intensity, transience, and impulsivity, all three of which tend to be discouraged in hierarchical classrooms. Formal instruction has typically been designed to control dynamic and propulsive students, like that precocious child who ignores the lesson while focusing on a mission of her own (Shonstrom, 2014). Curious kids criticize systems; they play; they jab at authority. Curiosity may not be radiating from the good boy or girl in the front of the class, but it may be from the kid in back, near the window, giving us heartburn with his attitude (Seal, 1995). Social critic Jennifer Fink (2015) writes,

> While my son still needs movement, still craves real-world learning, physical labor and ways to contribute to his family and his world, he's expected to spend most of his time in a desk, in a classroom, with 20-some other kids his age. He's not allowed to go outside at school when it's too cold or wet; he's expected to sit quietly in the library or auditorium during recess time. He's allowed few opportunities for "real" work; today, when you hand an 8-year-old a saw or allow him to start a fire, people look at you askance. One hundred and fifty years ago, my son would have been considered a model boy. Today, more often than not, he's considered a troublemaker.

For students to be able to express curiosity, they must feel entitled to ask and to seek, even if that means going against the grain and straying a bit in their explorations. In fact, curiosity is highly malleable. As educators, each of us has the power to nurture or crush it in others. For our most at-risk students, time to wonder and wander is essential. Not surprisingly, these students (of whom society expects the least) have had their curiosity the most dulled by rote learning, high restrictions, and classrooms focused on obedience. The only hope for these at-risk kids—and all kids—is to reinstate curiosity in our schools, by disengaging the education system from standardization—both in curricula and assessment (Shonstrom, 2014).

In order not to squash what comes naturally to students, we must allow for what philosopher Hannah Arendt called "the startling unexpectedness of all beginnings" (1961, p. 169), and what educational philosopher John Dewey (1916) called venturing into the unknown. The journey is equally as important for teachers as it is for students. Once we view ourselves as learners and explorers, more and more new things begin to seem possible (Greene, 1995). This represents a shift in the way we see the traditional role of a teacher, from one who asks and answers the questions, to one who elicits them. When science teacher Mark Knapp decided to do a unit on astronomy with his 6th graders, he knew almost nothing about astronomy, and told his class so. One kid exclaimed, "So now you're going to teach us something you know nothing about?" and Mark retorted, "You bet I am! Any homework that I assign you, I am going to do, myself. We're going to have a blast learning this together" (Fried, 2003, p. 111). Indeed, the curiosity classroom provides space for authentic and emergent experiences, possibility, and sense of ownership. This book is about empowering teachers to bring out and sustain curiosity in their students and to create a classroom in which it thrives.

When the teacher is a co-learner, the knowledge and insight that the students bring to the classroom is just as important, and equally worthy to learn, as that of the teachers (Freire, 1998). This doesn't mean that teachers need to let children's every question and moment of tinkering derail the lesson plan. But they can plan significant portions of the curriculum around the goal of inviting and encouraging children to pursue their curiosity, helping children figure out just what it is they want to know, and then showing them how to systematically go about getting the answers to their investigations and explorations. One of the most valuable functions a teacher can serve is to help children become more aware of, and deliberate about, their curiosity. Teacher Melissa Parent uses the KWL approach—What do we *know*? What do we *want* to know? And what have we *learned*?—to build her curriculum. For example, for an upcoming science unit on sound, she let her students know, "We need to study sound, but you get to decide what we learn about." This allowed her to focus her lesson prep on the aspects of sound that the class was genuinely interested in. She told them, "You are the designer of this unit" and reminded them that she's new to teaching and has a lot to learn herself. They knew immediately that she would not just be teaching things to them—that they would be learning things together (Fried, 2003, p. 119).

As teacher Carolyn Edwards points out, teaching as a co-learner is not about making things smooth or easy for the students. Quite the contrary. Teacher facilitators stimulate learning by making problems more complex, involved, and stimulating (Edwards, 1993). Helping students to follow their own interests and guide them in inquiry takes patience and hard work. "I'm in control of putting students in control," is how one educator put it—a responsibility that is much more complex than simply telling students what to do (Kohn, 1993).

The "We" Rather Than the "I"

Co-creating a curiosity classroom requires some degree of humility. Teachers have to cease being in charge and listen to the multitude of voices in the classroom with equal respect. One of the greatest novelists of all time, Leo Tolstoy, did something akin to this when he opened free schools—without programs, punishments, or rules—for local peasant children. In his piece "Who Should Learn Writing of Whom: Peasant Children of Us, or We from Peasant Children?" Tolstoy (1862/2015) described the barely literate children he worked with from the streets, whose self-awareness in writing and complexity in ideas rivaled his own. Learning from them was first strange and humiliating, but ultimately liberating, as Tolstoy and the children began to cowrite their stories. "Someone said, let's make this old man a wizard; someone else said, no, we don't need to do that, let him be just a soldier; no better have him rob them; no, that wouldn't fit the proverb" (p. 302). As soon as Tolstoy put his ego aside and stopped trying to instruct them, all children participated in writing the story. They became carried away with the process of creation itself, and this was the first step in the direction of inspiration. The children composed plotlines, created the characters, described their appearances in great detail, and invented individual episodes, all in clear linguistic form. The work was a true collaborative effort, in which the children felt themselves to be equal partners with an adult. Children spent sun up to sun down at their studies, and at the end of the day, they were still reluctant to leave the schoolhouse (Ashton-Warner, 2003). Tolstoy concluded that authentic education involves awakening in the child what already exists within him, and simply helping him to develop it (Vygotsky, 1967/2004).

When planning lessons, we must consider both our own objectives and goals and those of the students. Says one high school teacher, "Spending time on student generated interests is always much more gratifying and effective teaching in my opinion. Years later, it is often those moments that students have told me are the most memorable for them." When implementing lesson plans, we need to consider the learning goals that the students will have for themselves, as well as those we will have for them. Both sets of goals can be built upon the students' previous learning experiences. During assessment, documentation, and evaluation

Quick Recap

- All students–indeed, all humans–are curious.
- Supporting and scaffolding curiosity opens learners up to knowledge.
- Students' and teachers' curiosity can be combined to co-create a curiosity classroom.
- Creating a curiosity classroom shifts the traditional views of teaching and learning.

we can gather evidence of the effectiveness of the curriculum by identifying what was learned from both the teacher and student perspective (Wood & Attfield, 2005).

A Few Small Shifts

If the goal of school is innovation, creativity, and authentic progress, curiosity is a blessing. Curious children (i.e., all children) take risks, are intellectually playful, try things out, make productive mistakes, and learn deeply (Leslie, 2014). It takes just a few minor adjustments to transform any classroom into a hotbed of curiosity, beginning with a shift in how teachers view themselves, from teachers to teacher-learners who are curious in their own right about the processes of facilitating learning. In a way, doing this means setting up the classroom to support those skills that all learners begin with, such as the drive to explore, effortless learning, imagination, and intrinsic motivation. Finally, teachers must arrange the time, space, and orientation of the lessons in such a way for these inherent skills to bloom.

Children are superb learners. Each and every student is part of an evolutionary and developmental trajectory of learning that is structured into their biology and cultural context. When provided with the freedom and scaffolding to pursue their own interests, they can and will become efficient, joyful super-learners (Gray, 2013). In what ways are children inherently curious, and how can we support and extend that curiosity?

Small movements in perspective can transform the classroom into a container for an exciting new mode of learning together to happen. When students retain inherent curiosity and wonder, they will first go about asking questions, then seek ways of knowing and approach answers, and finally, begin again with more questions. When students adopt these habits of mind, they are unable to be stopped from learning throughout their lives. Teachers suddenly find themselves being surprised again, asking questions again, remembering what it was that they were so curious about once upon a time, and having a lot of fun. In the meantime, they begin creating a space where the most essential skills for deep learning are germinated—the curiosity classroom.

1

Promote Exploration and Experimentation

We shall not cease from exploration, and the end of all our exploring will be to arrive where we started and know the place for the first time.

—T. S. Eliot

The seeds of curiosity lie in exploring. Right from birth, children are agents of their own learning. Exploration is the act of seeking novelty. It involves experiencing the world in order to gain knowledge. How do young organisms come to be so immediately and fundamentally curious?

The Evolution of Curiosity: Exploratory Reflex

In the 1860s, German zoologist Alfred Brehm placed a covered box of snakes in the cage of several monkeys living in a zoo. When the monkeys lifted the lid, they were terrified, which is the typical reaction of monkeys to snakes. But then they did something rather odd (so odd that Charles Darwin was compelled to recreate the experiment himself). In spite of their fear, the monkeys could not resist reopening the lid of box to take another look at the snakes (Darwin, 1874). Since the publication of these findings in the book *Brehm's Life of Animals* (1864/2015), scientists have tested more than one hundred species of reptiles and mammals on their reactions to never-before-seen things. In all cases, the animals cannot resist novelty. In fact, attention to novelty is a fundamental feature of behavior shared by almost all organisms possessing nervous systems (Pisula, 2009). Novelty compels us to engage with different things, helping us survive by making sure that we pay attention to anything in our environment that can help or harm us.

Experimental psychologists in the last half-century have been fascinated with motivation as a prerequisite for learning. They have discovered that when we come in contact with ambiguous, complex, or conflicting information, our nervous systems become aroused, amping us up and forcing us to pay attention. When we are puzzled, we find a resolution very rewarding, which sets us up for efficient learning (Berlyne, 1966; Loewenstein, 1994). Neuroscientists have begun using functional magnetic resonance imaging (fMRI) to measure brain activation during new and interesting situations. When someone is curious, the brain areas underlying autonomic arousal and discomfort are more highly activated (e.g., the anterior insula and anterior cingulate cortex). Then, when the question at hand is satisfied, that is, when we gain access to relevant information, the brain regions associated with reward are activated (Jepma, Verdonschot, van Steenbergen, Rombouts, & Nieuwenhuis, 2012).

In the realm of human genetics, curiosity and a preference for newness have been linked to the migration of early humans to the far reaches of the earth. As we know, the first humans evolved in Africa about 150,000 years ago. About 100,000 years later, there was a major human migration out of Africa, with humans inhabiting all parts of the globe by about 12,000 years ago. Interestingly, recent studies have shown that those human groups who migrated the furthest from Africa also had a greater frequency of the genes linked to novelty seeking (specifically, the DRD4 exon 3 gene alleles 2R and 7R)

(Lehman & Stanley, 2011; Pisula, Turlejski, & Charles, 2013). In other words, the people who traveled the furthest from their origins may have had some biological propensity to check out and explore mysterious new places and things. As their brains grew larger, humans adapted by seeking out newness and engaging with exciting, novel experiences as a way to learn about the unknown.

The Development of Curiosity: Novel Places and Things

All wonder is the effect of novelty on ignorance.

—Samuel Johnson, *The Works of Samuel Johnson, LL.D.*

Just as curiosity underpins the movement and growth of groups of humans throughout evolutionary time, curiosity is also the driving force behind the growth and movement of each individual child in developmental time. Newborn babies come into the world able to hear, see, feel, taste, and touch things in their surroundings. Their sensory and nervous systems have evolved to respond to the demands of the world with spontaneous and involuntary actions (e.g., the sucking reflex, which ensures that infants will drink milk and be nourished). Reflexes are fixed action patterns that only last a short time, but they slowly turn into other more complex setups for learning. The greater the knowledge of the environment an infant has gained through curiosity, the more the possibility of adaptation to that environment (Kirkpatrick, 1903/2009). In fact, scientists at the National Institute of Child Health and Human Development recently discovered that the more energetically 5-month-old infants explored their surroundings, the more likely they were to perform well in school throughout childhood, all the way to high school (Bornstein, Hahn, & Suwalsky, 2013).

Babies marvel at sights, sounds, and patterns; they manipulate objects to test their physical properties; they stroke and mouth textures. Infants' tendency to be curious comes from the way their nervous systems are set up, and just as with animals, the exploratory drive springs from a perceptual preference for novelty. When given the choice, babies consistently look at, listen to, or play with things they have never experienced before (Diamond, 1995; Lipton & Spelke, 2003). One of the best moments in my early parenthood was catching my baby son noticing his hands for the first time. This discovery stands out like a metaphor for all of the learning experiences to come—his immediate and lasting interest in what those strange and wonderful appendages could do was his first step toward managing to control them. Novelty preference is an efficient way for infants' and young children's immature cognitive systems to process information. Novelty preference helps infants handle environmental changes. It then develops into the insatiable urge to explore and experience new things.

Children, like infants, spend their days in wonder. They can be counted on to open boxes and drawers, peek underneath furniture, and manipulate everything they can. Children make it their business to notice and observe, unearth and manipulate all of the things that might afford action. They use as many sensory systems as possible as a means to know, understand, and master their worlds, sometimes even without realizing it. As my toddler daughter Sonia so eloquently said after being told not to play with a porcelain vase at her great-grandmother's house, "I wasn't touching it, I was just looking at it with my hands."

Children's curiosity swells as they continue to explore, and this curious orientation can underpin engagement throughout K–12 education and beyond. For instance, one study showed that when elementary school-age children read books on topics *they were already wondering about*, they learned significantly more—including picking out more details and retaining what they read for longer periods of time (Engel, 2011). In another study, high school students showed increased engagement and increased enjoyment across school subjects when (1) they were appropriately challenged, (2) they were in control of how they spent their time, and (3) the in-subject activities were relevant to their own interests (Shernoff, Csikszentmihalyi, Schneider, & Shernoff, 2003). Furthermore, adolescents with widespread curiosity and interest in everyday life (including school) experience significantly better health and well-being (Hunter & Csikszentmihalyi, 2003).

Children's Brains Are Optimized for Exploration and Experimentation

Seong Min moved to the United States from Korea at age 4, when her father became a graduate student in chemistry. At first, she would sit timidly in the corner of her preschool classroom, venturing over to a table once in a while to draw or have a snack between tears. With virtually no knowledge of English it was difficult for her teachers to know what Seong Min was thinking or how well she was adjusting. Within about one month, Seong Min was no longer crying and gravitating to the corner of the room. She was playing with the kids outside and participating in the learning centers. By the end of four months, Seong Min was speaking English fluently and participating fully in the classroom! How was she able to learn so quickly?

Both children's and adults' brains are constantly wired and rewired (altered in their structure and function) as they encounter new experiences, understanding, and knowledge (Hensch, 2004). This is called neuroplasticity. Since early experiences have enhanced and longer lasting impacts on the brain (or "optimal neuroplasticity"), youth is the ripest learning period of the lifespan (Knudsen, 2004; Thompson-Schill, Ramscar, & Chrysikou, 2009; White, Hutka, Williams, & Moreno, 2013). It is no wonder children are curious to the core—novelty, exploration, and experimentation are wired in them!

During infancy and childhood, neurons (the cells of the brain) are ultra-sensitive to patterns in sensory input in their environments. Perceptual systems (like seeing, smelling, hearing, and touching) zoom in on, pick up, and organize the features of the child's world. Those pieces of information that are experienced regularly (e.g., the sounds of one's native language) are prioritized in the brain. This means that their neural representations become refined, tuning the child's perceptual systems in to only those specific types of stimulation and input (Kuhl & Rivera-Gaxiola, 2008; Werker & Tees, 1984).

At birth, infants can tell the difference between any sound in any of the world's languages. They can clearly hear the difference between /r/ and /l/, for example, when someone says /rock/ or /lock/. This skill functions to optimize learning language in the first year of life (Werker & Tees, 2005). By 1 year old, however, infants' ability to discriminate sounds in any of the world's languages declines, attuning them to only those sounds that they have been exposed to in their native language (Werker & Tees, 1984). The young brain has now been modified to hear only the necessary sounds and preferentially responds to them. Likewise, adults cannot discriminate or even hear differences in sounds that are not used in their native languages. This is why adult native speakers of many Asian languages have difficulty with the /r/ versus /l/ distinction in English. As a native speaker of English, no matter how carefully I listen or concentrate, I cannot hear the difference between the Hindi dental "d" sound in [dal] (which is a type of lentil), and the retroflex "d" sound in [ḍal] (which is a tree branch). My brain is fully attuned to the sounds I have grown up hearing in English (Kuhl, 2004; Werker & Tees, 1984).

Whereas it was incredibly quick and easy for 4-year-old Seong Min to learn to speak English, it took close to five years for her mother, Ji-Hye, to become fluent, and she was never able to speak like a native. Children who are introduced to a foreign language before the age of 7 can seamlessly pick up the grammar and phonology of the language and speak it without an accent. After age 7, the ease of learning new languages gradually declines until adulthood, regardless of the amount of experience with the new language, motivation to learn, cultural identification, or self-consciousness (Johnson & Newport, 1989). Like languages, early experience in music optimizes the child's brain to perceive and respond to new information. In fact, research has shown that most of history's prodigious musicians, such as Wolfgang Amadeus Mozart, Jimi Hendrix, and Yo-Yo Ma, began training before the age of 7 (White et al., 2013). These findings highlight what many parents and teachers have observed anecdotally: the younger the child, the more effortless the learning. This is because young brains are set up to explore and take in novel information.

Quick Recap

- Humans and animals reflexively seek out novelty.
- Being curious is evolutionarily adaptive.
- Infants and children have an insatiable urge to explore, know, understand, and master their worlds.
- Young brains are optimized for new information and change, making infants and children superior learners to older learners.
- Children's brains are optimized to learn from exploration and experimentation, not from passively listening to teachers.

Neuroscientist Jay Giedd studies how the human brain develops from birth through adolescence; he has clearly shown that for children younger than 7 or 8, learning via active exploration is far superior to learning from teacher-led explanation: "The trouble with over-structuring is that it discourages exploration," he says (Kohn, 2015, p. 4). Young brains thrive on the exploration and experimentation that are manifested in curiosity.

Scaffolding Exploration and Experimentation in the Classroom

The way that teachers feel about curiosity directly influences the way that their students explore and inquire. In one telling study, 3- and 4-year-olds were invited to play with a toy farm set while an experimenter sat nearby and behaved either in a friendly, encouraging way or an aloof, critical way. The children were then asked to guess what toys they were feeling, hidden behind a curtain. Children who had interacted with a friendly, approving experimenter were much quicker to begin exploring. They spent more time manipulating the toys they could not see, and they were more likely to guess the identity of the hidden object at the end of the session. In contrast, children who had had an aloof, critical experimenter showed significantly less task-related curiosity and exploratory behavior (Moore & Bulbulian, 1976).

In another study, researchers created a box with small novel objects in each of the drawers. They then put the box in kindergarten and 3rd grade classrooms and watched to see who came up to it, how many drawers each child opened, and how long each child spent examining the objects inside the drawers. What these researchers discovered was that in certain classrooms, 3rd graders were equally as curious as kindergartners: Just as many came up to the box quickly, opened all the drawers, and manipulated the contents. Children in both grades played with the little objects equally as long. But in other classrooms, regardless of grade, few children investigated the box. These classrooms, welcoming as they seemed at first glance, were places much less conducive to exploration. The researchers later discovered that there was a direct link between how much the teacher smiled and encouraged students and the level of curiosity the children expressed (Hackmann & Engel, 2002, cited in Engel, 2011).

Some teachers feel that they do not have the freedom or the time to allow children to get off-task and that following the children's interests or indulging tangents is a luxury that they cannot afford because they must ensure that students perform well on standardized tests. In a recent observation of kindergarten, 1st grade, and 5th grade classrooms, when the teachers relegated stretches of time to achieving very specific learning objectives, there just was not time for curiosity (Engel, 2011). How can teachers work within prescribed content standards *and* still encourage exploration and experimentation? The answer may simply be a matter of shifting our implicit attitudes toward curiosity.

In an interesting study with 8- and 9-year-olds, researchers emulated a school science project called The Bouncing Raisins (adding raisins to a mix of vinegar and baking soda, with the delightful result of the raisins bouncing up to the top of the glass) (Engel & Labella, 2011). At the end of the activity, the experimenter responded to the children differently. For half the children, she said something like, "You know what? I wonder what would happen if we dropped one of these [picking up a Skittle from the table] in the liquid instead of a raisin?" With the other half of the children, instead of picking up a Skittle and dropping it in, she simply cleaned the work area up a little, commenting as she did it, "I'm just going to tidy up a bit. I'll put these materials over here." Then the experimenter left the room. As she left, she said, "Feel free to do whatever you want while you are waiting for me. You can use the materials more, or draw with these crayons, or just wait. Whatever you want to do is fine." Children who had seen their guide deviate from the task to satisfy her own curiosity were much more likely to play with the materials, dropping raisins, Skittles, and other items into the liquid, stirring it, and adding other ingredients. Children who instead had seen her tidy up tended to do nothing at all while they waited. The lesson of this research is clear: Teachers' own behavior has a powerful effect on a child's disposition to explore (Engel & Labella, 2011).

Then, these researchers recreated the study, but this time designed it to measure how *teachers* would respond to spontaneous curiosity and exploration on the part of a child. In this case, teachers who volunteered to be participants were all asked to do the experiment with a "student" who was really working with the experimenters. The first group of teachers was told that the focus of the lesson was learning about science. The second group of teachers was told that the focus of the lesson was filling out a worksheet. The task with the jumping raisins was exactly the same, but this time the child (who was a part of the study) was instructed to stray from the instructions and put a Skittle into the glass. If the teacher asked the child what she was doing, the student was trained to reply, "I just wanted to see what would happen" (p. 191). The results were striking. Teachers who believed that the goal of the lesson was learning about science responded with interest and encouragement to the child's diversion, saying things like, "Oh, what are you trying?" or "Maybe we should see what this will do." But those teachers who had been subtly encouraged to focus on completing the worksheet said things like, "Oh wait a second, that's not on the instruction sheet" or "Whoops, that doesn't go in there." Like all humans, teachers are very susceptible to external influences. In this study, teachers' understanding of the goal of a block of time directly impacted how they responded when children wanted to spontaneously investigate (Engel & Randall, 2009).

Quick Recap

- Children with warm and encouraging teachers are more likely to explore their environments.
- A classroom's culture determines whether or not children will explore, regardless of age or grade level.
- When teachers model wonder and encourage spontaneous exploration, students are more willing to experiment.

Curiosity Technique to Try: Discovery Learning

Students benefit from the extra time it takes to discover on their own, even through trial and error. Often in my seminar courses, my students will spend a lot of time hashing out ideas. It is tempting to stop them, especially if they are not on the "right track." For example, in my Biased Brain course, I find it difficult to hear incorrect attempts about brain functionality such as, "Maybe this is how the brain works . . ." when I have more experience with the research literature. But I have to be patient and let them explore so they can discover insights and meaning on their own.

In the same spirit, 8th grade science teacher Muriel Hasek designs labs that are purposefully left open, so that her students can genuinely experiment with the materials and come to their own conclusions. For example, when she wanted her class to understand the properties of solutes and solvents, she just asked the students to begin mixing the liquids however they chose. The students devised their own systematic ways of testing the properties of the liquids and arrived at the understanding she had hoped for (that mixed solutions take on the characteristics of solvents), albeit in very divergent ways. Mistakes were a part of that process, but the goal went far beyond knowing properties of liquids to fostering an experimental mind frame. The next time you design a lesson with an intended discovery for the students, give them the opportunity to get in and muck around a bit. Let them know that finding answers is not always the goal, but the process of discovery can be just as rewarding.

Curiosity Technique to Try: *Choose Your Own Adventure* Lessons

Edward Packard always enjoyed telling his children bedtime stories. But when the fantastical plotlines became more complex, and he ran out of ideas, Edward began giving his kids choices: "Should the character walk through that door, or run the other way?" It didn't take long for him to realize that the children loved his stories all the more when *they* had a say in how the plots turned out. The interactive format became a storytelling device; it both locked in their attention and took advantage of their inherent creativity (Rossen, 2014). The *Choose Your Own Adventure* book series was officially launched in 1979. Children were suddenly allowed to become the main characters themselves—they were put in control while embodying the deep-sea explorer or the surgeon or the mountain climber ("If you put up the energy repulsion shields to try and escape the black hole, turn to page 22!"). They made choices—and that made them want to read.

You can design a lesson plan on the same premise. In biology, for example, a lesson on cells could lead students to six or seven different paths depending on their interests. Ask students to identify the parts of a plant cell under the microscope. Then, after labeling their diagram, they come to a choice point: "If you want to look at animal cells now, go to Table #2 and put an animal slide on" or "If you want to understand more deeply how the mitochondria work, go the computer research station and seek out some more information and images. Draw what you find." After seeing both animal and plant cells, they may have a choice to learn more about the history of the microscope, or to compare the cells of various animals or plants. They may have an option to create a more stylized image that integrates the parts of both a plant and animal cell at an art table. They can choose their level of analysis, zooming in or out, or moving laterally into new ways to discover cells based on their own interests. Your students will be engaged and excited to see where they wind up.

In Sum

Curiosity is at the heart of how humans change, learn, and grow—both in developmental and evolutionary time scales. Being biologically drawn to novelty helps us deal with changes in our environments and guides our attention to things we can discover, explore, and understand. When learners satisfy the urge to know, they feel really satisfied because they are activating the brain regions responsible for reward and pleasure. Young children's brains are most malleable and therefore are the most profoundly influenced by new experiences. Children are more superior learners than adults when it comes to some of the most complex and abstract concepts, like language and music.

When students' curiosity is activated, they learn more, and they learn better. Research shows that children's learning skyrockets when they read about things they are already wondering about, or when their active and spontaneous exploration guides their lessons (rather than simply learning teacher-imposed ideas or techniques). Finally, teachers who are more curious and engaged themselves have students who are more curious and engaged in kind.

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Cultivating Curiosity in K–12 Classrooms: How to Promote and Sustain Deep Learning relates to the engaged, supported, and challenged tenets.

WHOLE CHILD TENETS

1 HEALTHY
Each student enters school healthy and learns about and practices a healthy lifestyle.

2 SAFE
Each student learns in an environment that is physically and emotionally safe for students and adults.

3 ENGAGED
Each student is actively engaged in learning and is connected to the school and broader community.

4 SUPPORTED
Each student has access to personalized learning and is supported by qualified, caring adults.

5 CHALLENGED
Each student is challenged academically and prepared for success in college or further study and for employment and participation in a global environment.