Flexible Mindsets in Schools

Channelling Brain Power for Critical Thinking, Complex Problem-Solving and Creativity

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ROUTLEDGE

CHAPTER

2 What is the mechanism for Flexible Mindsets? Productive Puzzling and curiosity

The thrust of the Flexible Mindsets initiative is to empower people to direct their own learning. Self-directed learners actively focus mental energy on their goals and apply their learning to new and meaningful contexts, even when challenged. To take charge of their own learning, they must be driven by curiosity, a desire to grow and the love of learning. This ability to learn HOW to learn can be deliberately and consciously grown through direct engagement in active learning.

In this chapter, we will introduce the active learning concept of Productive Puzzling: the key mechanism we use to engage learners along the journey of Flexible Mindsets. In the next section of this book, Chapters 3 through 5 will highlight the implications of fixed mentalities and demonstrate how Flexible Mindsets can open the window for learning and provide tools for learning HOW to learn.

Socrates, an ancient Greek philosopher, believed that disciplined practice of thoughtful questioning enabled students to examine ideas logically and to determine the validity of those ideas. Charles Darwin, who illuminated the theory of evolution by natural selection, identified the central role of 'perplexed reflection' in science and learning. The Flexible Mindsets model builds upon these historical thinkers and newer ideas by incorporating recent work in mathematics education on the role of Productive Struggle (Warshauer 2015). In mathematics, Productive Struggle occurs in settings where it is safe to take risks, where students can share their struggle and where wrong answers are not seen as failures but rather opportunities to explore, grow and learn. By extension, *Productive Puzzling is being engrossed in a perplexing problem that is within your grasp but requires thinking, grappling and reasoning*. It is the springboard for Critical Thinking, Complex Problem-Solving and Creativity.

Curiosity is both the foundation of and partner to Productive Puzzling. *To be curious is to be inquisitive about the environment, an event, an object, a process or a concept*. Curiosity drives our desire to investigate and to learn. It is what happens when we encounter something unusual, novel or unexpected and it is marked by questions such as *I wonder what would happen if . . . ? How does this work? What could this be*

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used for? Productive Puzzling, by definition, must involve a dimension of feeling perplexed, leading us to ask, *Does this make sense? What else could we try? What are the possibilities?*

In this chapter, we will:

- explain why curiosity is important for deeper thinking and learning;
- provide straightforward information about what happens in the brain when we are curious; and
- introduce the five conditions that are necessary for Productive Puzzling.

Why is curiosity so important for deeper thinking and learning?

> Eating in a diner one day, I overheard a conversation between four college students. There was a 'machine' next to their table and one student said, "What's that?" The four friends then engaged in a collaborative process of examining parts of the object and discussing what each piece actually did. One student inferred that the titles listed along each row were songs from "the 70's – a long time ago." Eventually, the group concluded that you put coins in the slot, press a button that corresponds to a particular song and then that song is played by the device. They were satisfied with their answer and moved on to other topics of conversation. I thought to myself: I wonder what would have happened, if, when they first asked the question, I had leaned across and said, "It's a juke box."

Curiosity is just as important as IQ in determining how well students do in school and beyond. When curious, learners persevere, study and remember more. They read at a more meaningful level and attain higher grades (Silvia 2008). Curious students not only ask more questions and deeper questions, but they are also more active in seeking the answers. Without curiosity, would artist Kareem Abdul Jabbar have had success in such a wide variety of endeavours, from athleticism to film to authorship to global cultural advocacy? Would mathematician Grace Topper have been a pioneer in the field of technology and earned the National Medal of Technology and the Presidential Medal of Freedom? Would explorer Mae Jemison have evolved from a Peace Corps medical officer to become the first female African American astronaut, a founder of a nonprofit, an author and a science ambassador?

By motivating people to learn for its own sake, curiosity ensures that people will develop a broad set of knowledge, skills and experiences. When interested, students persist longer at learning tasks, spend more time studying, read more

deeply, remember more of what they read and get better grades in their classes (Silvia 2008). People seem to understand that curiosity enhances their motivation and performance. When faced with a boring task, people will use strategies to make it more interesting, such as working with a friend or making the task more complex (Sansone & Thoman 2005). Curiosity is the motivation for active learning.

What happens in the brain when we puzzle?

Trying new things has an adaptive function that has been critical for human evolution. Unfamiliar things often signal something dangerous or harmful. What we learn from new experiences can help us to respond effectively to unexpected circumstances and to counterbalance feelings of uncertainty and anxiety (Kashdan 2004).

The brain is wired for the survival functions of surveillance and alert. Curiosity is a response that activates the brain's arousal network. If the system detects something unusual, it can sound an alarm that is heard brain wide and this is when intrinsic alertness transforms into phasic alertness (Peterson & Posner 2012). Anything that is novel, unusual, unpredictable or distinctive puts our brains on alert and therefore our brains are wired to pay closer attention to them (Medina 2008).

In a recent research study, participants rated how curious they were to learn the answers to more than 100 trivia questions. The researchers then used fMRI scans to see what was happening in the brain when participants felt especially curious about the answer to a question (Gruber, Gelman & Ranganath 2014). The results revealed that curiosity prepares the brain for learning by acting like a vortex. The resulting void causes us to seek out stimulation. Thus curiosity puts the brain in a state that allows it to learn and retain new information. The implication of this is that if a teacher can arouse students' curiosity, they will be more engaged in learning. Another key finding from this research study is that curiosity can make learning a more rewarding experience for students. Researchers found that when curiosity had been sparked, there was increased brain activity in the hippocampus, which is involved in creating memories as well as the circuitry related to reward and pleasure. When these circuits are aroused, dopamine – the 'feel good' chemical in our brain – is released. So, piquing students' curiosity can help them remember lessons and make their learning experiences pleasurable.

Educators have long recognised that students learn better when new material is linked to prior knowledge. Existing knowledge, concepts and systems are easier to process than novel material. Activating this base makes it easier to grapple with more difficult cognitive work. There is no thinking without knowing (Willingham 2009). There is no meaningful learning without active engagement.

Based on evolutionary theories, scientists can now better explain how our brains are wired to pay attention to information connected to existing memories (Medina 2008). Our 10,000-year old brains were not designed for the world we live in today. They were built when we walked or ran many miles a day. This is

why our brains crave exercise and we get a brain boost when we get up and move. Our brains are designed to process visual information quickly and can pay attention for about ten minutes. This adaptive function is rooted in evolution. Humans who failed to instantaneously attend to threatening situations did not live long enough to pass on their genes. Thus, we are programmed to use our previous experiences to accurately remember threatening situations and to direct *where* we pay attention.

Thinking, on the other hand, is slow and effortful and our brains are not built for it. It is not efficient and reliable to think. Thinking is hard work so it is not surprising that people have to really motivate themselves to engage in it.

Thinking was not evolutionarily helpful (see Figure 2.1). Stop and think and you might end up . . .

Figure 2.1 The evolutionary value of NOT thinking

So much of our brain's real estate is taken up by activities related to seeing and moving. Our brains are not wired to think in the ways that are demanded of us in traditional classroom settings. They are naturally curious and designed to scan the environment, explore and alert us to threats. We are powerful and natural explorers (Medina 2008).

Educational practices are not aligned with what we now know about brain development. We are expecting students to exert mental effort for several hours during the school day and then go home and do hours of homework, leaving no time for processing, reflecting, integrating and connecting. When made to perform on traditional school-based tasks, our brains are being asked to do things that run contrary to their evolutionary purpose. Since thinking is such hard work, and does not provide rewards that stimulate dopamine release, children rarely experience joy in academic learning. If we want students to be motivated to engage in thinking, we need to convince them that their mental work will be worth it.

One effective way to do this is to use curiosity to engage learners in exploration, invention and improvisation. We all weigh the potential pleasure of solving a problem against the mental effort required. If the challenge is too difficult or too easy, our brains disengage from the process. If the recipe is perfectly balanced, we are tapping into curiosity and ensuring that students enjoy thinking and learning (Willingham 2009).

The potential to pique curiosity lies in experiences that are emotionally laden and meaningful (Medina 2008). Incongruity is particularly effective for engaging our brains. If you want learners to become engaged and ask questions, present something that is unexpected, odd, absurd, juxtaposed or humorous.

Guidelines for piquing curiosity

1 Consider that content and delivery matter

A group of students attends a field trip to the science museum, specifically to watch the IMAX film celebrating the 50th anniversary of Apollo 11. This documentary film uses original footage to describe the 1969 Apollo 11 mission, the first spaceflight in which men walked on the Moon. Ciana is an explorer by nature: she loves science, especially astronomy, and has a precise replica of the solar system on the ceiling of her bedroom. Esther, on the other hand, is an artist: she writes beautiful poetry and loves epic shows such as *Star Trek: Discovery*. The factual style and technical information in *Apollo 11* fuse naturally with Ciana's preexisting scientific knowledge and her head is buzzing with new questions and ideas about future possibilities. Esther has an entirely different experience. She comprehends very little about basic concepts such as gravity and acceleration and can't access most of the material. The dry style of presentation does nothing to grab her attention and her imagination is stifled.

There are aspects of thinking we enjoy because we get a sense of pleasure from finding solutions (solving problems). There are also lots of things that require thinking that we would never choose to do and many others that would simply bore us. While the type of content matters – we are more curious about things that interest us – the delivery of the content is what matters most when it comes to piquing curiosity. When content is presented through a medium we enjoy, is connected to a story or includes an element of surprise, even the most boring topic can spur our curiosity (Willingham 2009).

2 Remember inspiration can't be forced

Salvador Dali, a 20th-century surrealist painter, used to sit in a chair with keys in his hand along with an upside down plate on the floor and let his mind wander until he fell asleep. His hand would release the keys as soon as he slipped into a deeper state of sleep and the sound of the keys clinking on a metal plate would wake him up. This little amount of rest is just enough to awaken creativity. In this state, his mind brought together distant ideas in a new way. He believed that this process led to some of his best ideas.

Somewhere deep within each of us is an affinity, *something that, when we are in the midst of it, engages us to the point that we don't even notice what is happening around us*. The outside world just disappears. When we are engrossed in an affinity, time moves so quickly that we are unaware that it has passed. All the energy and brain power that we use does not even feel like hard work (Silvia 2006). Inspiration flows from the thinking that we do when our brains are in the diffuse mode. Using the metaphor of a brain as a flashlight, the diffuse mode casts a broad, scattered light whereas the focused mode is concentrated light (Oakley & Sejnowski 2018). Our brains enter the diffuse mode during moments when we are not explicitly thinking, such as when listening to music, exercising, taking a walk, mind-wandering and sleeping (Gkiokas 2018).

In contrast to mindfulness which focuses the brain, mind-wandering allows the brain to be more creative (Zomorodi 2017). Purposeful learning occurs when we shift flexibly between focused thinking and meandering. So, when we need to destress, we meditate; when we want inspiration, we daydream.

3 Make it comprehensible

There are two types of evaluations that learners make when faced with a challenge (Silvia 2005; 2008). One assessment is the level of novelty: the degree to which something is new, unexpected, surprising or intriguing. Decades of research show that new and unexpected events can pique our curiosity (Berlyne 1960). Secondly, we judge whether or not a challenge is comprehensible. We think about our skills, knowledge and resources to deal with an event (Lazarus 1991). If we perceive a goal as incomprehensible, we give up. In the case of curiosity, we are responding to an unexpected situation. If we perceive an event as both new and as comprehensible, curiosity is activated (Silvia 2008). Perceiving something as being comprehensible is the bridge between feeling curious and feeling bored or discouraged. Feeling lost and confused shuts down our learning. Novelty, coupled with the seeds of comprehension, sparks learning.

4 Build in time off-task (to space out)

We often see boredom as a negative state and something to be avoided. Boredom is actually the place we all need to visit as an intermediary between busywork and inspiration. Boredom is a state of mind that happens when we take away distractions such as cell phones, video games and television. It is not enough to simply remove distractions. True boredom happens when we have 'nothing to do' and no one is demanding anything of us. Boredom alerts us that we are no longer pursuing purposeful goals. The current goal is no longer satisfactory, attractive or meaningful (Elpidorou 2014). This leaves us feeling restless, agitated and uncomfortable (Zomorodi 2017) and we crave escape. In order to avoid feeling trapped in an unfulfilling state, we begin searching for something to stimulate us, something that

is not readily available in our immediate surroundings. Boredom is both a warning and a push (Elpidorou 2014).

The push of boredom allows us to 'space out'. Our thoughts don't stop just because there is nothing to do with those thoughts. It may appear that the brain is shutting down; it is actually digging into a vast trove of memories, imagining future possibilities, dissecting our interactions with other people and reflecting on who we are. "It feels like we're wasting time when we wait for the longest red light in the world to turn green, but the brain is putting ideas and events into perspective" (Zomorodi 2017, p. 21).

Boredom is necessary.

5 Let it be. Don't give the answer

When babies learn to sit up and crawl, they cannot yet walk. Would we carry all babies everywhere with us, rather than watch them repeatedly try to stand up and fall over? How heavy would they get before we decided they were too heavy to carry around? Would it then be *too late* for them to learn how to walk?

Make it comfortable for learners to stop and think. Adults who want to help often do things for a child which can feed into 'I can't' self-perceptions. Try to wait before jumping in, even if it feels uncomfortable. It takes lots of practice to learn to find the perfectly balanced moment to intervene: after allowing time for experiencing challenge, but before a child has become discouraged.

Some traditional approaches to education involve three steps in learning: watching a model, being assisted and then doing it on your own. These approaches are effective for a range of learning experiences. What they don't do is spark curiosity. They are too predictable and we already know what's going to happen. Developmentally, children also need time and space to explore, make mistakes and struggle. Without struggle, children don't get to experience the benefits of hard work. They may have started out feeling curious, but if we hand them the answers, then a task appears to be too easy and no longer captures their curiosity. This reinforces beliefs that everything must come to us instantaneously and that struggle is not worthwhile. We must avoid cheating students of feeling capable and learning how to do things on their own.

The brain needs to pause to give time for the prefrontal cortex to kick in. This helps us to think and respond, instead of just reacting. Allowing children time to struggle forces them to question, plan, solve problems, organise and grapple with concepts. The more opportunities we give them to tackle appropriately challenging work, the more likely they will be to develop the neural networks to solve future problems.

Adults need to be okay with waiting and suspend the instinct to jump in and rescue children with the answers. We have to be able to observe children's confusion, frustration and discouragement. However, 'letting it be' doesn't mean we should just do nothing. Figuring out when to intervene requires us to take into account the nature of the task, a child's skill set for solving similar problems and

the child's tolerance for frustration. When you do intervene, don't do it for them. Rein in your impulse to fix things. Let them know you are there to support them by asking questions such as, "How can I help? Tell me about ____. What have you tried so far? *What else could you try?*"

As Willingham observes, "People are naturally curious, but we are not naturally good thinkers; unless the cognitive conditions are right, we will avoid thinking" (2009, p. 9). In other words, if we always hand out the answer, curiosity will disappear, and with it, Critical Thinking, Complex Problem-Solving and Creativity.

When you think about school, what typically comes to mind? Your own experiences when you were in school? Your children's experiences? Perhaps a particular subject you found fascinating or one that was incredibly boring? The image that comes into my mind is everyday brains doing everyday things. Much of this consists of content download, where students wait to have the teacher tell them what to do or what to think. This type of concrete knowledge is important as the basis for learning, but it is not enough.

Beyond concrete learning, effective teachers find creative ways to pique curiosity. They may use novelty to introduce a topic, present problems that are intriguing and design projects that expand our understanding of the world. They may also use predictions to build anticipation and hook learners into wanting to know more. The simple act of starting a lesson with a question such as "What did we learn yesterday?" instead of providing a summary of the previous lesson can make a significant difference (Agarwal & Bain 2019). These instances achieve the goal of opening up neural pathways for learning. Without further intervention, most brains tend to revert to a more passive state of simply trying to absorb information. Piquing curiosity activates the arousal network and signals potential pleasure in the brain. It allows learners to reach a stage where they are becoming increasingly self-directed, where they can say "get out of my way, but not too far" (Heick 2019). Ultimately, self-reflection empowers learners to effect qualitative changes in their own thinking. Piquing curiosity gets the brain ready for Productive Puzzling and puzzling feeds curiosity.

What are the necessary conditions for Productive Puzzling?

Learning activities that promote Productive Puzzling require five conditions (see Figure 2.2). The foundation must be firmly established by designing an environment that builds trusting relationships and encourages taking risks for learning. The second and third conditions operate interdependently: sufficient challenge to spark curiosity, coupled with solutions that are within reach. Ideally, puzzling is set up to ensure that there are multiple strategies for the solution and, preferably, more than one possible outcome. Opportunities for reflection are built into the process and facilitated after the completion of the activity.

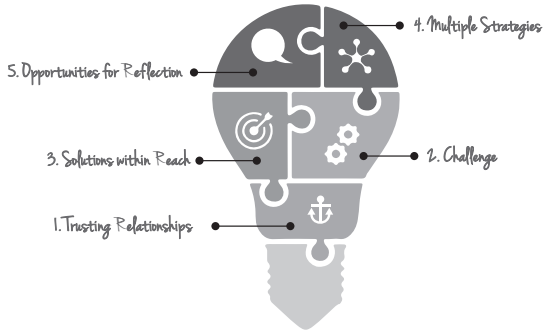

Figure 2.2 The five conditions for Productive Puzzling

Condition 1: trusting relationships for risk-taking

Trust arises from a number of factors within a given environment as well as the actions and reactions of other people. To summarise briefly, it is important to:

- set up physical spaces that invite exploration and co-creation;
- share that the cornerstone of learning is identifying what we don't know and grappling with it;
- clarify that our brains learn best through mistakes and trial and error;
- model the value of mistakes by 'talking aloud' through our own errors;
- celebrate mistakes and their role in creativity, innovation and inventions;
- communicate in ways that build trusting relationships; and
- explicitly troubleshoot challenges and obstacles.

Chapter 4 provides more detail on how to open the window for learning and build trusting relationships for students to ask questions, make mistakes and take risks for learning.

Conditions 2 and 3: challenge and solutions within reach

Having created an environment characterised by trust, we can then begin to introduce conceptual challenges to learners (see Figure 2.3).

A challenge is something difficult that requires mental effort and determination. It is the gap between what is already known and what is yet to be learned. People tend to seek out novelty, but we quickly discard problems that are too easy or too difficult (Willingham 2009). If we start a Sudoku puzzle and solve it quickly and easily, we won't be interested in another puzzle at the same level of difficulty. Conversely, if we can't even figure out the first few numbers, then we will become frustrated and give up.

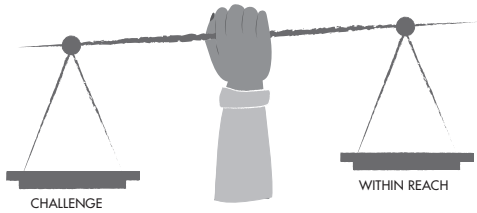

Figure 2.3 Productive Puzzling balances challenge with solutions that are within reach

As we strive to change the mindsets of students, we place increasing emphasis on the role of challenge for making brains smarter. Setting goals that are both challenging and achievable is largely a matter of structuring tasks in advance. It is crafted from an educator's expertise in concert with relationships that build on the knowledge of individual students. Having set up a challenging puzzle for students, the role of the adult is to facilitate deeper puzzling. We express our confidence in learners to solve puzzles by affording them time in which to ponder and by providing specific guiding questions to promote perseverance and flexible strategy use. Effective interventions focus on breaking a puzzle down into smaller, manageable chunks; encouraging learners to ask questions and explain their thinking; and using their responses to guide the type of open-ended questions you ask next.

Condition 4: multiple strategies

There is more than one trail to the top of the mountain.

Given the pressures of current-day curricula, speed and accuracy in producing the correct answers are highly valued. There is little time for children to explore and figure things out. IQ tests, which are supposed to measure intelligence, rely heavily on already knowing the right answers and on timed responses. Children who take the time to reason and try different strategies to figure out answers are penalised, often resulting in lower scores than children who are less reflective. We inadvertently reinforce the misconception that knowing is superior to not knowing by only showing excitement and pride in students when they give us the right answers. What would it look like and sound like in classrooms all over the world if teachers gave students a high five every time they identified something they didn't know?

A Flexible Mindset is characterised by the ability to try something out, figure out what works and what doesn't and then say: *Does this make sense? What else can we try? What are the possibilities?*

These questions encapsulate the ability to shift perspectives and adapt flexibly when learning. Using open-ended prompts and sharing ideas is critical for assisting

learners to recognise that there are multiple ways to reason, many strategies that can lead to a solution and endless possibilities for what something can become.

When learners shift flexibly, they are comfortable with 'not knowing' (Duckworth 2006). They take time to generate and evaluate multiple strategies (Meltzer 2010). It is rare that educational practices include direct instruction highlighting the value of different thoughts and strategies. Before selecting puzzles that can be solved using multiple strategies, set the climate in the classroom by building trusting relationships. Ensure that learners feel secure with the sharing of differing thoughts.

Condition 5: opportunities for reflection

During Productive Puzzling, children initially are engaged in reflection when they are asked to think about the process. However, the greatest opportunities for reflection often happen at the end of an activity or lesson. Metacognition and reflection work hand in hand. As learners become increasingly self-aware, they are better able to reflect upon 'What Works When'. Direct strategy instruction has been proven to improve how students transfer learning, use knowledge creatively and reflect on processes (Meltzer 2013). Strategies such as retrieval practice help students to identify what they do and do not know and focus on deepening their understanding (Agarwal & Bain 2019).

Students need to 'go deep' in reflecting upon their strengths and challenges, as well as the strategies that work best in a given situation. Predicting how they would approach something differently in the future is critical for self-directed learning. Once students have begun to understand and use the language of self-reflection, dialogue in the classroom can explore puzzles at greater depths.

To stoke Productive Puzzling, students must learn to ask and answer the kinds of questions that deepen exploration beyond initial curiosity (see 'Carefully Crafted Questions' in Chapter 5). Adults are charged with teaching students the language of learning: how to think, listen and speak in ways that facilitate deeper learning (Wilson 2015).

Productive Puzzling is the underlying mechanism for Flexible Mindsets. This chapter has defined the five conditions necessary for Productive Puzzling. Applying these principles consistently through the Flexible Mindsets Spiral of Reflective Learning allows educators to take charge in their own classrooms (see Table 2.1). These practices create a culture where students feel comfortable taking learning-related risks, use strategies flexibly and persevere when challenged. Noticing the incongruous, the unexpected, the unfamiliar and the things that provoke a feeling of discomfort entices us to delve further and sets us on course for developing agency in our own learning.

In the next section, Chapter 3 will elaborate on the implications of fixed mentalities in closing the window for learning. Chapter 4 will set the foundation by exploring ways to build trusting relationships so students feel comfortable asking

questions, making mistakes and taking risks for learning (condition 1). From this base, we can nurture the capacity for learners to engage in Productive Puzzling. In Chapter 5, we will briefly describe the value of balancing challenges (condition 2) with attainable solutions (condition 3). We then explain how to teach learners about strategies (condition 4) and deliver feedback to engage them in self-reflection (condition 5).

Table 2.1 The Flexible Mindsets Spiral of Reflective Learning: Productive Puzzling

 **BE METACOGNITIVE**	Scan your lesson plans for opportunities to introduce puzzles. How will you help students understand the type of content that is best suited to using thinking and reasoning for Productive Puzzling versus content that is factual and can be learned with more traditional methods?
 **MODEL**	How will you model and encourage the questions that help us to use curiosity to explore new depths? "I wonder what would happen if . . ." "How can we use this new knowledge to imagine a different way of thinking about what we are learning?"
 **ASK QUESTIONS AND AFFORD TIME**	How will you schedule brief moments for unprogrammed time for students to puzzle, reflect or get bored?
 **USE SHARING AS A SPRINGBOARD**	How will you build in opportunities for students to share their stories about delving deeply into puzzles and how working hard leads to greater satisfaction? "I saw your group had a long discussion when you were struggling with building this robot. Share your challenges with the class and how you were able to work through them and find a solution together. How did you feel in the middle of the difficult work and how do you feel about having made the robot work? How did grappling with the challenges contribute to the process?"
 **THINK ON YOUR FEET**	How will you respond to unexpected moments by encouraging your students to turn curve balls into puzzles to be explored? "You probably weren't expecting this to happen. Why do you think it happened and how can you explore it further?"

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