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with Susan Hensley

THE i5 APPROACH

LESSON PLANNING THAT TEACHES THINKING AND FOSTERS INNOVATION

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THE i5 APPROACH

LESSON PLANNING THAT TEACHES THINKING AND FOSTERS INNOVATION

Preface

Veronica Armstrong, a high school biology teacher, called me on Skype to discuss the new unit plans she was drafting in order to reflect the revised sequence of science courses at her school. "Jane," she said, "before we start on planning, do you mind if we talk a bit about the online course I am taking?" The class was great, she told me. It was called "Using Technology in the Classroom." Veronica explained that the first part of the syllabus was dedicated to knowing about the state's commitment to provide 1:1 technology (one student, one device) in every classroom. Then the instructor showed lots of exciting apps for students to use on personal devices in addition to numerous software programs available to teachers.

Listening to Veronica, it was clear how much she genuinely enjoyed learning about the different ways to incorporate technology into her classes. Making podcasts, she laughed, was the real hit among the teachers. Veronica commented that she thought her students would like some of the programs and apps she'd seen, but she was concerned about whether the technology would really help them become critical and creative thinkers and learn the biology content more effectively. "Am I out of line to wonder if using devices in class really leads to better learning?" she asked.

The Conundrum

It is no secret, Veronica continued, that students don't always use personal devices in classrooms in the way teachers intend. Students might appear to be actively taking notes on a laptop or researching online, but anyone strolling behind them would be sure to catch that instant screen change signaling the student was hoping to avoid being caught doing something unrelated to the lesson. "It was bad enough before personal devices when students stopped paying attention," Veronica noted. "But now, technology seems to encourage distraction! If they are distracted, it is a chore to get them thinking about science."

Veronica confessed a second concern about student engagement and learning. "Please do not think I am complaining, but making a podcast and incorporating apps into my lessons requires a lot of planning on my part," she said. "For all that preparation, the result should be gains in student achievement. Does research confirm that my teaching efforts to use and encourage students to use technology in the classroom improves learning?" She said she had asked this question in her course's online chat, but noted that, "The instructors and other participants only responded by posting studies indicating that students, parents, and teachers all reported higher motivation and satisfaction with implementing technology; there was nothing about thinking and improving learning."

My conversations with teachers indicate the same. Students seem more motivated to work on assignments when they use technology, but this has not necessarily translated into increases in test scores or grades. Some surveys reveal, and some teachers report, that students find class more engaging when they can use personal devices or electronic notebooks (Cox, 2015). Parents seem to concur, saying that their children like class more when they use technology (National Association of Elementary School Principals, 2013). It makes perfect sense, since students and everyone else seem to use technology effortlessly in everyday life. But very few studies show that incorporating technology into lessons improves overall student achievement (Hattie, 2009).

In fact, it seems the opposite may be true. In an article in *Psychological Science*, Pam Mueller and Daniel Oppenheimer (2014) share that taking notes on a laptop is a bad idea if you want to remember the information later. Their research showed that people who wrote out their notes longhand learned more deeply and remembered information much longer than those who word processed their notes on a digital device. If research shows that longhand note taking increases knowledge retention and deepens understanding, should teachers encourage students to use electronic note-taking programs? How can we advocate for "going paperless" in schools if going paperless does not improve learning?

Nicolas Carr, a journalist and Pulitzer Prize finalist, wrote about the quandary of digital vs. print in *The Shallows: What the Internet Is Doing to Our Brains* (2011). The title of the book foreshadows what he found: the internet is making us forget. Carr recounts his personal quest to determine how using technology was affecting his output; ultimately, he concluded that he could not. The problem, he says, was that he forgot much of what he read online, meaning that he was not able to think about topics in depth—and forgetting information is an anathema to a journalist. Acknowledging the risk of becoming known as a modern-day Socrates, who allegedly renounced the alphabet and writing, Carr cautions that using technology may increase consumption, but it's not likely to improve production.

In schools today, we use technology to present material and increase engagement, but is the time and money invested in classroom technology worth what seem to be negligible gains in achievement? I was determined to find a way to ensure that in-class technology use would magnify gains in student learning, productivity, and thinking.

Using Technology

I began the way Nicolas Carr did—by addressing my own experience using technology.

Electronic devices give me access to an almost infinite amount of information and visual representations through pictures or video. I use a laptop or other device to read news, studies, and books online, and I often click on links to see pictures or videos to give meaning to what I am reading. Inevitably, I send an e-mail or text, and I often contact the recipient afterward to discuss the information I've sent. Without a doubt, technology improves my life by giving me immediate access to information, images, and interaction with others, and this capability is not trivial. Perhaps the key to effective teaching with technology involves teaching students to tap into those environments—information and image seeking and interaction—rather than choosing an app or a program for a task.

To clarify, here is a story from my teaching past. In the days before students had personal devices in the classroom, I assigned research tasks that sent students to the textbook, the encyclopedia, or other print material in the school library's limited collection. For example, in a unit on the Industrial Revolution, I might have directed students to read about the conditions of workers in garment factories, meatpacking factories, and coal mines. Although I intended for them to find information that would allow for thoughtful comparison of these different working environments, support reasoned conclusions about the lives of these workers, and inspire original perspectives on the economies of the age, what students usually produced were well-organized sets of the same, predictable observations and conclusions. What I now realize was that the three or four paragraphs in the textbook, the encyclopedia, and our school library's print collection didn't give my students enough information to do what I wanted them to do—engage in deep thinking to generate original ideas. The resources available to them left them with literally *not enough to think about*. What's more, the student products didn't give me the evidence I needed to evaluate their analytical abilities or assess deep learning. I was left to determine grades by focusing on criteria such as whether they met the project deadlines, the appearance of the material, and presentation style.

Today, students using technology could approach a task focused on researching working conditions during the Industrial Revolution very differently. With ready access to the internet, they could synthesize information from numerous sources, including diaries, charts of the ages of workers, and documentation of work injuries. Images, photographic stills and video interviews with descendants of those who worked in factories or mines would provide critical details and generate interest. The task could easily be expanded beyond two or three types of environments to many other workplaces, and students could use the wealth of information available to engage in analyses and draw a wide range of conclusions about the impact of industrialization on different geographic areas or population settlements. Let's take a moment here to appreciate how invaluable digital devices are for tasks that require research and information gathering, because they provide such a breadth of information and images to support and drive inquiry, questioning, and reflection.

For many of us, digital devices are synonymous with communication. As events happen around the world, we reach out to others to seek clarification, find new or more or expertly curated information, get feedback, and receive correction. Now think of how students working on the Industrial Revolution task might interact with one another by editing shared text files and using video chats or messaging to join in conversations among themselves or with outside experts.

As I engaged in this kind of reflection, the need for using technology to teach thinking in class started coming into focus. The way to plan lessons for using technology in the classroom had to include opportunities for students to learn how to effectively access information and images, and for students to engage in some form of interaction for correction and clarification.

Eureka!

In *The New Executive Brain: Frontal Lobes in a Complex World* (2009) cognitive neuroscientist Elkhonon Goldberg writes about the prefrontal cortex, the brain's control center. It's here that each of us combines the information that we take in through our senses, processes it with labels and language, factors in our past or current interactions and experiences with one another and the world—and turns this all into *meaning.* Goldberg describes human cognition as forward looking and gives a name to the process humans use to manipulate and transform current and past information into a model of something that does not yet exist—*thinking*.

Reading Goldberg was my *Eureka!* moment.

The frontal lobes of the human brain are designed to seek out and process sensory information to use to generate new ideas. Consider students' lives in the noisy (ears), odorous (nose), and highly stimulating (eyes, touch, taste) outside world, and then consider a classroom where students have been primarily relegated to listening (ears) and seeing (eyes). If using technology in the classroom could increase sensory data about any given topic by providing an expanded supply of information, images, and interaction, then students would more likely do what comes naturally to the brain: think to generate new ideas. We may not be able to provide the tasting and touching sense in schools, but brain studies show that brains can make amazing adaptations when there is a need to compensate (Doidge, 2007). When teachers design lessons that expand the range of sensory inputs available to students, they increase the odds that students will engage in critical and creative thinking—otherwise known as *inquiry.*

And there I had my criteria for using digital devices not only to support learning, but also to build stronger thinking. Within lessons, technology should be employed in ways that encourage students to access *information*, *images*, and *interaction* that will power *inquiry* and lead to the generation of new ideas—otherwise known as *innovation.* The i5 approach was born.

The i5 Approach

To recap, the concept of the i5 approach emerged from blending the expectation that students use technology in class with the neurological explanation that a person needs sensory information—literally, something to "think about"—before he or she can generate original ideas.

Today, we can move forward from schools where chalkboards and hornbooks provided the environment for only the three "r"s (*r*eading, '*r*iting, and '*r*ithmetic) to the 21st century classroom where digital devices provide the learning environment for the five "i"s: information + images + interaction + inquiry = innovation.

The i5 approach is a powerful lens that any teacher, from primary to secondary school and beyond, can use when planning lessons. Ask yourself, when should students look up more *information*? How would an *image*, video, or audio component deepen a student's understanding of a topic? Would *interacting* or receiving ongoing feedback through shared documents or instant communication clarify, correct, or deepen understanding that students can use to make meaning?

The i5 approach was immediately compelling to me, but I realized that it could not be about technology alone; teaching the *inquiry* skills needs focused attention. Think of it this way: in a world where information is only a click away, teachers should help students acquire and develop the critical and creative thinking skills to transform information, images, and interaction through inquiry into *innovation*.

Back to the Future

Nearly every school mission statement and strategic plan promises to increase critical and creative thinking skills, and many teachers say they use Bloom's taxonomy when planning and delivering instruction. But it's fair to say that most teachers do not explicitly teach thinking skills. My next step in refining the i5 approach was to figure out the best way to teach the thinking skills.

Looking back to the 1980s, the concept of teaching thinking in schools came to the forefront in education. Professional development for teachers in the United States responded to the memorable *A Nation at Risk* report issued in 1983, which identified an urgent goal for U.S. educators. Schools had to change; teachers needed to teach students how to become critical and creative thinkers.

If you search online for thinking skills programs that germinated during this time, you will find de Bono's *CoRT Thinking* (1986), Richard Paul and Linda Elder's *Critical Thinking* (2014), Art Costa's *Developing Minds* (1985), and Dimensions of Learning, a framework that I coauthored with our team at McREL Laboratory (Marzano et al., 1997). Based on evidence that most teachers wanted to teach thinking but needed a curriculum to show them how to do it, the different programs offered steps for teaching critical and creative thinking. What was not obvious to us at the time was that students and teachers, who faced a paucity of information in print materials, literally lacked the information that merited using robust thinking or inquiry processes. Teachers sensed the problem, but in the print world of the 1980s, we did not see any easy solution.

Then, the standards movement of the 1990s happened. The standards that emerged might have expanded and deepened content knowledge in a manner that would have given students more to "think about" and fueled critical and creative thinking, but political agendas steered educators away from this. The energy and funding that went into developing standards for testing and testing for standards was a devastating distraction to educators.

Thirty years later, not all is lost; in fact, with the dramatic advance of technology since 2007 and the widespread popularity and greater affordability of smartphones and tablets, timing may be in our favor. Based on the current standards and the available online content, there is plenty for students to think about. Students can search broadly for information and images about topics, and interact with many others, but they still need explicit instruction on how to inquire: analyze and evaluate what they find. We can revisit the thinking skills program, update the skills based on current neurological research, and produce the steps for teachers to teach inquiry.

This is a good time to clarify that in this book, the phrase *inquiry skills* is used synonymously with *critical and creative thinking skills. To inquire* is to ask a question and seek information, but *inquiry* involves studying, scrutinizing, and exploring. Some programs use the word to describe any unit of study that includes gathering information about a topic to resolve a problem, clarify doubts, or increase understanding. As noted, with the i5 approach, we make the distinction that teachers need to provide students with explicit instruction for learning inquiry or thinking skills; we do not assume that students know how to apply the steps of thinking to new information they encounter in school.

Rather than encouraging teachers to have students use technology, we can encourage teachers to teach students critical and creative thinking skills, *and that requires technology use*.

In This Book

In this book, my colleague and contributing author Susan Hensley and I describe that process. We explain how to design lessons that thoughtfully incorporate the wealth of inputs and options that technology makes available in today's classrooms and how to explicitly teach critical and creative thinking in a way that makes students skilled and powerful thinkers and ready innovators.

Chapter 1 gives an overview of teaching thinking for innovation, drawing on the works of neuroscientists who write for public awareness and practical uses. V. S. Ramachandran (2011), author of *The Tell-Tale Brain*, writes, "Brain science has advanced at an astonishing pace over the last 15 years, lending fresh perspectives on—well, just about everything" (p. xii). Although Ramachandran is well-versed in the new research, he has not abandoned traditional approaches that get positive results. For example, he suggests that his amputee patients seeking therapy for phantom limb pain use a cardboard box and a mirror at home rather than endure trips to hospitals to wait to use high-tech machinery. Ramachandran's work was a reminder to me that many teachers work in schools that do not have the latest technology—schools where students might still learn in a shared computer lab or use low-cost netbooks. The i5 approach doesn't require state-of-the-art technology; it works in any classroom with whatever technology is available to help teach students to think.

Even in the 21st century, teaching begins with a lesson plan. Chapter 2 explains where to start using the i5 approach and suggests that it helps to have a lesson-planning schema designed particularly for this purpose. We make the case, then, for the research-based schema called GANAG, introduced in *Improving Student Learning One Teacher at a Time* (Pollock, 2007). The first step in the lesson prompts the teacher to decide whether to teach procedural knowledge or to pursue a declarative goal that requires thinking. When lessons structured with GANAG are enriched with the i5 approach, students are best positioned for critical and creative thinking.

Chapters 3, 4, 5, and 6 delve deeply into the inquiry skills, exploring the four categories of association, synthesis, analysis, and taking action. They draw upon *Dimensions of Learning* (Marzano et al., 1997), where my colleagues and I produced a taxonomy of thinking skills; I rebooted the material for today's teacher, updating the steps of these skills to align with what we have learned over the past 20 years of research into how people learn, with special attention to the last step: generating new ideas, or innovating. These chapters focus on the component steps or skills, how to teach them, and how to incorporate them into lessons. Susan, an executive director of curriculum and instruction in the Rogers (Ark.) public school system, contributed many examples and recommendations for teachers. Working side-by-side with teachers in her district, she creates and teaches many classroom lessons. In these chapters, we present examples of lessons that have been enriched with the i5 approach to empower students to use technology to develop higher-order thinking skills and engage in innovation. Note that all of the lessons we present in the book are real lessons. We are grateful to the teachers who have shared them, many of whom have allowed us to identify them by name.

In Chapter 7, we revisit the iconic Horace Smith, the high school English teacher from Ted Sizer's (1984) fictitious Franklin High School, who faced a tsunami of school reforms in the 1980s. What would Horace do in a classroom where students bring their own devices?

Would the seasoned veteran change his teaching? Would his students learn better? Teachers, principals, and superintendents note that despite providing resources and professional development, technology implementation often sputters and fails like many other initiatives. What does new research on forming habits tell us about how Horace could implement the i5 approach in today's classroom?

The appendix that closes the book presents a reference list of the thinking skills explored in Chapters 3 through 6. It can guide you through each of these skills' steps and help you with the process of "i5-ing" your own lessons.

The Streetlamp

Let's return to Veronica, the science teacher who is learning to incorporate technology but hopes the efforts will result in gains in student thinking and learning. Reflecting on her question about the research reminded me of a vignette that Stuart Firestein (2012) includes in his book *Ignorance: How It Drives Science.*

Firestein relays the story of a scientist searching for his lost car keys in the area under a bright streetlamp one night. A passing stranger offers to help, but their search is unsuccessful. Finally, the stranger asks the scientist if he is certain that he dropped his keys in the area directly under the light.

To the stranger's surprise, the scientist answers that no, he actually lost the keys in another spot, pointing to a dark area of the street. When the stranger asks why he is not searching for the keys over there, the scientist responds that the light is much better under the streetlamp.

The anecdote seems set up to have us judge the scientist as silly for not looking in the right place, but Firestein shares the story to inspire discovery and innovation. He proposes that scientists seek information in areas where they have ignorance, not knowledge, and always look in the place where there is a possibility of finding something new, something useful, and something good. Firestein notes that he does not view science with a capital "S" and does not follow a set of rules to churn out hard, cold facts; in fact, he writes, "Science is groping and probing, and poking, and some bumbling, and bungling… and it's somehow exhilarating" (p. 2).

Similarly, teachers like Veronica do not view teaching with a capital "T," nor do they obediently follow a set of lesson planning rules or believe their sole purpose in the classroom is to ensure students master standards and hard, cold facts. Teaching, like science, is probing, poking, bumbling, and bungling resources to prepare lessons. Teaching is discovering ways to teach every child in school to probe, poke, bumble, and bungle as well, learning deeply and learning to generate new ideas for their own generation and the next.

Some schools implement technology initiatives by looking for keys in the dark place where they are sure they have knowledge. Those schools will move ahead with 1:1 mobile device programs and celebrate students' satisfaction related to the use of technology, even if the devices are used for repetitive, low-level tasks. Some schools will provide the tools but miss the goal of using technology to teach students to be critical and creative thinkers.

The i5 approach is what I discovered when I searched for my lost keys under the bright streetlamp. I hope that teachers who read this book will use technology in order to teach students how to access an almost infinite amount of *information*, *imagery*, and *interaction*, but also that they will explicitly teach *inquiry* skills so students can practice becoming proficient at *innovation*. Now *that* would be exhilarating.

JEP

1

Teaching Thinking

Henry Molaison, or “HM,” became a celebrity in the field of neuroscience—not for what he knew, but for what he did not know. In 1953, a surgeon removed a part of Henry’s brain, the hippocampi, in an effort to reduce the occurrence of debilitating seizures. When Henry, then 27 years old, awoke from surgery, he could eat, breathe, walk, and talk; he seemed recovered and no longer suffered seizures. Soon, however, it became obvious that Henry had only a few long-term memories, and he was able to remember new experiences for just a couple of minutes, at the most.

Until his death in 2008, HM lived in “permanent present tense,” as Suzanne Corkin put it in her 2013 book of that name. HM’s procedural memory (what he could “do”) was intact, but he had lost the ability to encode, store, and retrieve declarative information (what he needed to “know”). Over the next few years, neuropsychologist Dr. Brenda Milner, would point to his case as proof that people process procedural and declarative knowledge differently. It turns out that the surgeon removed the part of the brain that processes declarative knowledge, so Henry lost the need to think.

Thinking Naturally and Thinking *Better*

Humans with intact and healthy brains think. We *need* to think. We must sort through the thousands of bits of information we take in from the world around us, anticipate multiple reactions that might occur in response to any number of events, plan and predict consequences, and evaluate our actions to make adjustments. In other words, our daily interactions require us to think.

Many of our biological processes are automatic and happen naturally, but many of our procedural capabilities are developed through effort and practice. For example, in life and in school, we can get better at speaking a language, playing an instrument, singing a song, or building a cabinet. Can we get better at thinking?

In *The Brain That Changes Itself* (2007), psychiatrist Norman Doidge says yes. He describes Michael Merzenich's research that focuses on helping people think better. For example, Doidge writes, Merzenich and his team have developed practical exercises to support what they call the executive functions of the frontal lobes, including, "focusing on goals, extracting themes from what we perceive, and making decisions. The exercises are also designed to help people categorize things, follow complex instructions, and strengthen associative memory, which helps put people, places, and things into context" (2007, p. 90). In summary, Doidge notes that Merzenich's research shows that we can teach people to think better, and Merzenich and others offer training and exercises to support the executive functions. The next question is, are these newly acquired understandings of how the brain works something we can apply in schools?

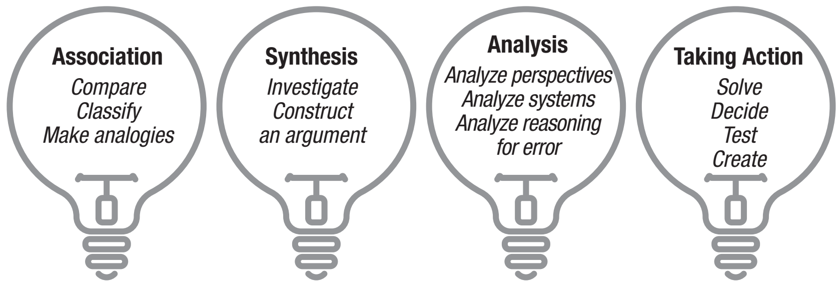
We say yes. With so much information, imagery, and interaction to process from the outside environment, thinking—inquiry—is something of a survival mechanism. If students can become better thinkers through practice, and research says they can, making this a goal for schooling is both logical and correct. In schools, teachers are familiar with "guided" and "independent" practice time for students, recognizing that it's a necessary component of instruction aimed at building proficiency with procedural curriculum goals. Teachers can teach students to use and practice thinking skills to make meaning of the declarative knowledge in the curriculum and use that knowledge to generate original ideas and products.

Inquiry skills are a keystone of the i5 approach, which identifies 12 processes that teachers can teach students to use to gain deeper understanding of declarative content knowledge and become better thinkers overall. We group these processes into four categories (see Figure 1.1):

- **Association**
  Compare: Describe how items are the same and different.
  Classify: Group items together based on shared traits.
  Make analogies: Identify a relationship or pattern between a known and an unknown situation.
- **Synthesis**
  Investigate: Explain the theme of a topic, including anything that is ambiguous or contradictory.
  Construct an argument: Make a claim supported by evidence and examples.
- **Analysis**
  Analyze perspectives: Consider multiple takes on an issue.
  Analyze systems: Know how the parts of a system impact the whole.
  Analyze reasoning for error: Recognize errors in thinking.
- **Taking Action**
  Solve: Navigate obstacles to find a good solution to a problem.
  Decide: Select from among seemingly equal choices.
  Test: Observe, hypothesize, experiment, and conclude.
  Create: Design products or processes to meet standards and serve specific ends.

Taken together, these skills can be described as *the skills of inquiry*, and they've become familiar parts of the curriculum over the past few decades. Chances are, the lessons taught in most classrooms already feature most or all the skills listed above, and students are expected to use each of these processes to varying degrees.

FIGURE 1.1
The Skills of Inquiry—aka Thinking Skills



But the critical question is whether teachers are deliberately teaching the skills of inquiry in the same way we might teach the steps of adding fractions, conjugating verbs, creating a website, making an omelet, or serving a volleyball? Do we teach students to compare, for example, or do we assign a task assuming they know how to compare? Do we expect students to be able to analyze points of view, or do we teach them to do this, step-by-step, and then give them the practice they need to get better doing it?

Following the i5 approach means ensuring that the lessons you deliver provide an opportunity for all students to learn to use inquiry skills to process all the declarative knowledge that we teach in school. And it means teaching, scaffolding, and reviewing these skills to help students become better, more innovative thinkers.

Two Types of Knowledge

This is a good place to clarify the confusion about declarative and procedural knowledge. These two types of knowledge are well-illuminated by David Bainbridge, the author of a book that looks at both the anatomy of the brain and the history of neuroscience, *Beyond the Zonules of Zinn: A Fantastic Journey Through Your Brain* (2008). Bainbridge explains that our brains process procedural and declarative knowledge differently. He describes how our ancestors spent a good amount of time seeking food as they moved through the rich natural environment, where they honed their abilities to see, hear, smell, taste, and touch. We have inherited brains that can move our bodies in productive ways. Exactly as our dogs and cats at home do, we use our cerebellum, or the "little brain," to move (and breathe, digest, circulate blood, etc.). These functions are automatic; *procedural knowledge* is the name we use for knowledge we have practiced enough times so that, once learned, its application *seems* automatic. With a bit of DNA and practice, some skills become automatic so that we can do them—*reproduce these actions*—without thinking.

Bainbridge continues his discussion about the need to procure food and inserts the idea that humans evolved beyond moving toward food (or away from it, in the case that they might become food to other animals) to remembering where food was stored, which food was in which area, and where it might be available again. Our ancestors generated a vast library of labels for this previously experienced information so that they could use it later and in new situations. This led to a much deeper demand than could be handled by just the "little brain." Our "bigger" brains grew to include a prefrontal cortex—an area of the brain that processes the type of knowledge known as *declarative knowledge*, or anything we know that we might "declare." Although the mechanism has not been pinpointed, we know that the evolution of language in humans coincides with the emergence of our prefrontal cortex. The human brains developed the ability to move our bodies but also to move ideas. The process for moving ideas needed a name to distinguish it from procedural knowledge, and it got one: *thinking*.

To become more proficient at skills—or procedural knowledge—a person practices. To productively use declarative knowledge, a person thinks. Thinking skills are the brain's way of processing declarative information for retention so that it can be manipulated and reorganized with other information to generate new ways to act.

The process of thinking is slow, and the thinker requires information and time to remember, reorganize, and produce results. In school, some tasks intend for students to reproduce knowledge (procedural goals), and other tasks intend for students to produce a new version of the knowledge (declarative goals).

Now let's identify insights about teaching thinking skills. A teacher can identify whether he or she wants students to learn a topic as procedural knowledge (to reproduce it) or as declarative knowledge (to retain and reorganize to produce an original insight). If the teacher decides to teach a topic procedurally, the students will need lots of practice and feedback. But if the teacher decides to teach information declaratively, then the students will need lots of information and an opportunity to learn and use the steps to one of the thinking skills.

Remember Bainbridge's description of hunters and gatherers moving through the rich environment and gathering input? Compared to the wilderness or a savannah, most classrooms come up short in terms of environmental stimuli; students generally hear and see, but there aren't that many opportunities to use the other senses of touching, tasting, and smelling the learning topic. That means that students need to compensate for the lack of stimulation to gather enough information, imagery, and interaction to set the thinking or inquiry processes in motion. The solution is to use digital devices.

Using technology compensates for the lack of stimulation in a print-only classroom. Complex sensory input is now more readily accessible than ever before, and students can view video and images, hear audio, and actively engage with what seems to be unlimited content and information. In short, the i5 approach informs the "why" of using technology in the classroom and directs digital devices into being a critical element of classroom instruction. It's a means to enrich the way students receive content and create the environment for developing better thinking.

As a side note, technology can be used in a way that improves students' procedural knowledge, too. Access to video, for example, allows students to watch a skill demonstration—and review it multiple times, studying each step as closely and as often as necessary. Access to video recording equipment in the classroom allows teachers and students to document skill development, to track progress, acquire feedback, and practice and perfect repetitive procedures. The caveat is that using technology can bolster procedural knowledge, but it cannot replace carrying out the procedure. You can read about swimming online, but most people agree that until you get in the water and start swimming, you will not become a better swimmer.

Technology deployed to develop declarative knowledge has fewer limitations. It gives students access to a seemingly unlimited amount of information to "think about" compared to what would be available in a non-digital classroom. Because our main concern in this book is the possibilities for teaching thinking that technology has opened we will be focusing on declarative knowledge and the thinking skills, leaving the discussion of using technology to improve procedural knowledge to another author.

How to "i5" Your Lessons

In the simplest application of the i5 approach, revising a current lesson is a matter of answering the "i5 questions":

1. How would more *information* help students see the details and breadth of this lesson's topic?
2. How would visual *images* or nonlinguistic representations add meaning to the topic or give it context?
3. How would *interacting* with others, live or through social media, provide clarifying, correcting, and useful feedback?
4. How would teaching or incorporating *inquiry*—a thinking skill—boost active engagement and questioning with the topic to increase aptitude?
5. What *innovative* ideas or insights could students produce in conjunction with this learning?

Let's take a closer look at each of these key questions and determine why they are so important before we move into lesson planning for teaching thinking and fostering innovation in Chapter 2.

The Role of Information

*How would more **information** help students see both the details and breadth of a topic?*

Just 20 years ago, a standard U.S. history textbook provided only one example of a constitution: the U.S. Constitution. Today, students can research information about "constitutions" online and find documents from dozens of countries in their native languages and translated into English. This breadth of content adds to students' understanding of nations and lays the groundwork for in-depth analysis using a higher-order thinking skill such as comparing different documents to find similarities and differences among them.

In *Think Better: An Innovator's Guide to Productive Thinking* (2008), Tom Hurson writes, "More than any other commodity, information is everywhere. Not only can almost anyone access almost anything at almost no cost, but, unlike corn and wheat, information doesn't have to be consumed to be used. Quite the opposite: the more it's used, the more it grows" (pp. 9–10).

In a classroom today, when Donna Martin teaches a poem by Gwendolyn Brooks or a novel by Gabriel García Márquez, her students have access to biographies, images of where and how these writers lived, critiques by both those who support and those who question their work, and, of course, recommended works shared by hundreds of people around the world. Ms. Martin says that when she is planning to deliver the new information in her lessons, digital sources are critical. She can direct students to visit websites to find biographical or autobiographical information; she teaches students to search for the right information they need to answer questions but also to delve deeper.

In Belinda Parini's physical education classes, students learn about factors that affect fatigue. Ms. Parini says she now plans instruction time to include short segments for students to search for information online.

By reading athletes' own writings, accessing data charts, and studying current science articles that support the knowledge of metabolic changes, students improve their abilities to predict fatigue factors and solutions in various case studies.

When planning to teach lessons today, many teachers search online to prepare their lectures or to present information to students. But teachers can also, and should also, have students use digital devices during class to search for information related to the learning goal and then teach them how to evaluate what they find for usefulness and accuracy. In the i5 approach, teachers and students access information during instruction to increase access to declarative knowledge, but also to become better thinkers.

The Role of Images

How would visual ***images*** *or video add meaning to the topic or give it context?*

Images are powerful. Henry Luce, the publisher of *Time* magazine, acquired *Life* magazine in 1936 so that readers could *see* the news, not just read about it. This new magazine literally changed the way its readers saw the world. A simple photograph of a young girl named Anne Frank gave a face to the Holocaust on the August 18, 1958, cover of *Life*. Similarly, the televised broadcast of the first step on the Moon's surface left an enduring footprint in viewers' memories.

Second grade teacher Lauren Eide enhances her students' comprehension in a social studies class as they learn about different cultures. They read *Four Feet, Two Sandals,* by Karen Lynn Williams and Khadra Mohammed (2007). Online, they see maps of areas to determine where the people in the book live and learn about challenges faced by residents of different geographic areas. They watch an online video about life in a refugee camp. The images and information support the reading, so that students discuss, question, and logically deduce what could happen in these parts of the world.

In *Classroom Instruction That Works* (Marzano, Pickering, & Pollock, 2001), Jane and her colleagues showed nonlinguistic representation as a technique with the high probability of improving student achievement, at $d = 0.75$. Stated differently, when students can see an image or a video of a person delivering an address in a theatrical production, hear sounds of animals, or see how chemical processes change substances through virtual experimentation, they attend to the content and remember it much better so they will store and use it again.

Some researchers say that 70 to 90 percent of the information that comes to the brain is visual. Because 40 percent of all nerve fibers connected to the brain are linked to the retina, the brain can process visual information 60,000 times faster than it processes text (Visual Teaching Alliance, n.d.). David Bainbridge (2008) suggests that when we discuss how humans process information, we should use "image" as a verb, not a noun; we *image* information as it comes to us, as our brains work to resolve the features of a new object or stimulus into a familiar picture so that we can respond to it more effectively.

When high school math teacher Becky Efurd teaches about parabolas, she shows a video of high jumpers in field competition as an illustration of an otherwise abstract concept. In health class, students can watch videos to find out how to tape a foot after an injury. Only a few years ago, students in Gary Nunnally's economics class learned about supply chains and the importance of coffee trade via a photo in the textbook, a few short paragraphs, and his lecture. Today, Mr. Nunnally plans lessons so his students can virtually visit a coffee plantation in Manizales, Colombia, where they are able to access information regarding the supply and markets. Students can view commodities trading online, in real time. They may not be able to smell the coffee via the internet, but they can access and experience information about the production and economy of coffee in engaging ways that encourage further research.

Using technology in the classroom, either by providing images or cuing students to search for an image, allows more students to more quickly engage in the topic of the lesson. Incorporating nonlinguistic representations in lessons provides opportunities for immediate engagement at any grade level and especially for students who speak another language at home. In much the same way that *Life* transformed magazine reading, teachers using digital devices and the i5 approach can transform classroom learning.

The Role of Interaction

*How would **interacting** with others, live and through social media, provide clarifying and useful feedback?*

As social beings, we crave interaction. Humans constantly seek, receive, and respond to feedback. Personal digital devices make such interaction in an educational setting a reality for students, thanks to the individualized and often immediate feedback they can provide. Websites and programs such as Google Hangouts, instant messaging, texting, Skype, Facetime, and even the more traditional e-mail exchanges are optimal tools for interaction. We are lucky to live in a time of instant communication.

As we consider how to encourage students to interact with others, however, we must address two challenges that are brought to our attention by neuroscience research. The first is that human brains developed to seek distractions. Because distractibility (for food sources) is a trait that helped our ancestors survive, it persists in the gene pool today. In the hands of children, digital devices offer zillions of personal distractions, so using technology in the classroom will usually trigger a positive reaction from students; they will like it.

The second challenge is that humans are natural socializers or, as David Bainbridge (2008) describes us, "compulsive communicators" (p. 307). Today all of us seem to use digital devices to feed our compulsion. Introduce a social media network to teenagers who are still amygdalating (OK, that's not a real word, but it implies emoting instead of reasoning) and lack fully-formed prefrontal cortices, and these students will be all but compelled to interact at the click of a keyboard or the swipe of a fingertip.

At this point, you might be thinking that interaction may not be such an advantage to learning in a classroom, but it can be highly productive. In the language arts classroom, students writing a story or a speech can receive immediate feedback if they share a file or work on a shared document. In world language classes, students can practice conversation via Skype links between Boston and Bucharest or Cedar Rapids and Caracas. In science, interaction in lab settings epitomizes the work of pairs of young scientists who use digital devices to make quick searches, check accuracy, and organize information.

The sobering aspect of distraction and socialization is that as much as we humans enjoy them, we are wired to set goals. In any situation, humans set goals and then strive to connect new information to previously experienced knowledge so we act, either quickly or in well-planned or strategically thoughtful ways, to meet those goals. To be specific, in a classroom setting the learning intention is critical. If it is clear to students at the onset of the lesson, the human need for interaction (pair-sharing, talking at tables, shoulder partners) can be used as a tool to encourage them to interact for clarification, correction, and to seek more information to meet the goal or objective for the lesson.

Feedback is necessary for effective learning and can come from multiple sources. The essence of interaction in the i5 approach is that students learn to seek input or correction from the teacher, from themselves by searching, and from others to clarify information or rectify mistakes. Obtaining feedback in a classroom often means frequent and timely interaction and students can use digital devices to focus and streamline these exchanges.

The Role of Inquiry

How would teaching ***inquiry*** *or a thinking skill boost active engagement and questioning with the topic to increase aptitude?*

The i5 approach for planning lessons supports teaching and developing students' thinking power. It's built on findings about the executive functions offered by the neuroscientists, research on effective instructional approaches that formed the basis of *Classroom Instruction That Works* (Marzano et al., 2001) and a series of thinking skills that Jane and these same colleagues developed in the book, *Dimensions of Learning* (Marzano et al., 1997). And although teaching thinking is compatible with various lesson planning approaches, it is best facilitated through a schema called the Master Learners model (GANAG) first published in *Improving Student Learning One Teacher at a Time* (Pollock, 2007). In *Classroom Instruction That Works*, Jane and her colleagues found that three areas of thinking showed high effect sizes: identifying similarities and differences (d = 1.61), generating and testing hypotheses (d = 0.61), and questioning (d = 0.59). The inquiry aspect of the i5 approach emerged from the research in those categories of thinking. The 12 thinking skills in Figure 1.1 are the focus of inquiry instruction.

Students come to class with the natural ability to think in the world around them; our challenge as teachers is to teach them to effectively think about math, humanities, music, and the other content we teach in school. The i5 approach guides teachers to do just that—and to enlist digital devices in the effort.

Fostering Innovation

What ***innovative*** *ideas or original presentations could students produce?*

Elkhonon Goldberg (2009) writes about how the prefrontal cortex powers the actions we take. Humans with healthy brains are constantly encoding, storing, and retrieving information in response to newly sensed information. Thinking is powered by memory. We can retrieve and apply that information to the various new tasks, decisions, situations, and interactions we face. And it's the frontal lobes we rely on to do that work.

According to Goldberg, what makes humans unique is that we can generate a mental picture of something that does not exist—like a mermaid, for instance. Before Disney animation, and even before libraries filled with illustrated volumes, people were calling up images of fish they had seen and combining it with the image of a human being to create the visual concept of a mermaid; this was thanks to the function of their prefrontal cortices. In short, the frontal lobe is used to produce original thoughts with newly sensed or remembered information. Humans use the prefrontal cortex to think so that they can innovate.

Economist Tom Grasty (2012), considering what skills will be beneficial within society in the years ahead, shares an interesting distinction between invention and innovation:

> In its purest sense, "invention" can be defined as the creation of a product or introduction of a process for the first time. "Innovation," on the other hand, occurs if someone improves on or makes a significant contribution to an existing product, process or service. (para. 5)

Grasty notes that after the invention of the transistor, most of the products we use today could arguably be considered "innovations," rather than inventions. Innovation, he believes, is what we need to be teaching students.

With access to digital devices and the internet, students can seek information or view images to add meaning to a topic, interact with others to seek feedback, and use all those memories to power their own ideas, through inquiry, to innovate.

The i5 Student and 21st Century Skills

Susan's son, Samuel, is a typical high school student. Technology use is part of his daily life. In addition to using the internet to download songs and videos for entertainment, he searches for information to help him learn the newest dance steps, refine his soccer moves, improve and record his trumpet practice, or find the instructions for assembling a new bookcase for his bedroom. He interacts with friends through texts and shares images through social media. Samuel games with friends he will never meet face-to-face.

Our professional challenge is to teach students like Samuel to apply 21st century skills to their academic lives as effortlessly as they apply them to their personal lives. There are several different interest groups with varying definitions of what students should know and be able to do in the 21st century. What exactly are the 21st century skills we want students to use?

The Partnership for 21st Century Learning (P21, formerly known as Partnership for 21st Century Skills) coalition has spent more than a decade bringing 21st century skills to the center of education in the United States and has developed a guiding framework (P21, n.d.). Bernie Trilling and Charles Fadel, authors of *21st Century Skills* (2009), narrow the list to three main categories: learning and innovation skills, digital literacy skills, and life and career skills.

The International Society for Technology Education (ISTE) produced the National Education Technology Standards for Students in 2009. The revised 2016 version describes indicators for seven standards, including Empowered Learner, Digital Citizen, Knowledge Constructor, Innovative Designer, Computational Thinker, Creative Communicator, and Global Collaborator.

What they have in common is that they both attempt to describe what students in the digital era need to know and be able to do to demonstrate knowledge and to use available tools to research, create, and communicate.

The i5 approach provides a way to teach students to meet these indicators in the classroom, and it helps produce citizens who will succeed in the increasingly digital world. If the P21 and ISTE/NETS standards describe what we want for our graduates, the i5 approach describes how to pursue it.

The Other "i"

To paraphrase Ralph Waldo Emerson, "Every artist began as an amateur." The intent of the i5 approach is to guide our amateur students to use digital resources to become their very best selves. Inspired by Emerson, the i5 approach encourages teachers to teach so that students learn to think for themselves, actively self-assess, and relentlessly seek and use resources available to become their very best. The goal for students using the i5 approach can be captured with another "i"—to be a contributing *individual*.

3

Teaching the Skills of Association

Looking out the window, Jane noticed four students crossing the street one behind the other, one barefoot; it reminded her of *Abbey Road,* the iconic Beatles' album cover.

Did mentioning *Abbey Road* immediately bring to mind the image of four men on a London crosswalk, one of them barefoot? That detail alone may begin to trigger teenage memories for some of you who spent days listening carefully to lyrics and scrutinizing album covers to find clues as to whether the rumor—that "Paul Is Dead"—was true.

Then your mind starts churning, remembering the rumor that Paul McCartney died in a car accident. Had the Fab Four covered this up and replaced McCartney with a look-alike named Billy Shears? It was said that the album cover depicted a funeral procession. Fans saw John dressed in white as a preacher, Ringo in black as a funeral director, and George in denim as the gravedigger. The barefoot Paul was the corpse, because in some cultures, the dead are buried without shoes. From the police van to the blue dress on the back cover, from the cigarette in Paul's right hand to the license plate, the *Abbey Road* cover art presented all kinds of clues that could be interpreted as confirmation that Paul McCartney had died. And although "Paul Is Dead" may have been a hoax or an elaborate marketing scheme, here's a truth that is undeniable: association is real.

Why Teach Association?

The human brain connects what is known to us from our past with what we sense in the present. In his book about the anatomy of the brain, *Beyond the Zonules of Zinn*, David Bainbridge (2008) explains that the cerebral cortex engages high-level linking of lower-level sensory processing—what we see, hear, touch, taste, and smell—to establish context and interpretation. Bainbridge calls this high-level linking, "association" and adds that "there is a great deal of space for all that tantalizing 'association' to go on, in the large cerebral cortex of a human" (p. 274). It is within that "great deal of space" that we hope our students make associations to the topics we teach.

In general terms, the prefrontal cortex conducts the traffic of both physical and mental activity, receiving inputs and determining action. The hippocampus cross-references all new information with existing memories, and those collections of associations are reported back to the conductor to decide whether to act, to move, or to forget.

The fact that association is such a natural and necessary part of surviving in a world of sensory information might answer the question of why teaching using association seems fairly easy to do. Often quoted, Hebb's catchphrase about learning new information speaks directly to this action: "Neurons that fire together, wire together" (Panksepp & Biven, 2012). When stimulated by new information, clusters of neurons are more likely to fire together simultaneously, again helping us make sense (provide context, perceive, and interpret) by remembering a host of other associations instead of just single facts. Association provides increased neural currency, so it makes sense to teach it explicitly when students are learning new declarative information.

How do we use information about the Beatles, brain research, and brainstorming by association as a practical tactic for teaching lessons that target thinking? In this chapter, we'll look at strategies to help students develop three inquiry skills that target association—**comparing**, **classifying**, and **creating analogies—**and at classroom examples of how the i5 approach galvanizes innovation.

Comparing

Comparing is the "simple connection" part of association. Finding similarities and differences among the topics or products around us is a practical way to deal with the flood of incoming information or sensory data. In *Classroom Instruction That Works* (Marzano et al., 2001), Jane and her colleagues identified the strategy of finding similarities and differences between and among items as having a high probability of increasing student learning (d = 1.61). Students have a much greater chance of retaining information and being able to use it to generate new ideas when they find associations or similarities and differences among items.

Ask yourself: What kinds of **comparing tasks** do you assign, and for what purposes? Then, with these tasks in mind, ask yourself the **i5 questions**:

1. How else could the students and I search for *information?*
2. How else could we use visual *images* and nonlinguistic representations to add meaning?
3. How could I encourage students to *interact* with others, live or through social media, to obtain and provide feedback?
4. How could I teach the *inquiry* skill—comparing—to deepen knowledge?
5. How could I plan for the students to use the application to generate *innovative* insights and products related to the lesson goals?

The Procedure

The first instinct when teaching comparison might be to give directions for filling in a Venn diagram, or sketch out a process that looks like this:

1. Identify two items.
2. Indicate what about them is similar.
3. Indicate what about them is different.
4. Draw a conclusion and produce a product.

Reasonable, right? Except that following those steps leads students to describe obvious parallels and not venture very deeply into the content. Notably, what's missing is the pivotal step that transforms comparing into a higher-order inquiry process. Figure 3.1 shows a better alternative—the steps involved in making a higher-order comparison. Specifically look at Step 2. Note that when you're teaching this skill—or any other—it can help to translate the steps into simpler or more

FIGURE 3.1
How to Compare

The objective: Describe how items are the same or different.

Steps in the Process	Simplified Language
1. Identify the items to compare. (Comparing three or more items makes the comparison more ambiguous and, therefore, more complex.)	1. Name the items to compare.
2. Identify features by which to associate the items.	2. Tell some features about the items.
3. State how the items are similar or different based on the features.	3. Say how the items are the same or different based on the features.
4. Summarize findings to generate new ideas or insights.	4. Tell what you know now (share a new idea) or could do with the information (create a new product).

student-friendly language, especially in the elementary grades and with English language learners. We've provided a simplified-language version of this skill in the figure (see column 2) and will do so for all the thinking skills addressed in the chapters ahead.

The pivotal step in the comparison process that marks the transition from simple recall to higher-order thinking is Step 2, identifying features or characteristics that will serve as the basis for comparison. Teachers can teach students how to identify unusual characteristics to deliver a more complex comparison. For example, say we're setting out to compare world leaders. At first, one might consider intellect, previous accomplishments, or grit. But, to press on, one might consider factors such as

- Responses to controversial international events
- Noteworthy or unique initiatives set into motion
- Examples of humility or humanitarianism

Naming these features provides motivation to search for the *information* and view *images* or videos of evidence. Considering each leader by each feature drives us to *interact* with others to clarify the accuracy of the information to further define the topic, check perceptions using new sources, and seek other interpretations. This *inquiry* process generates new insights or *innovative ideas*—from which one can form well-supported opinions about what makes the best kind of world leader. To increase the complexity of students' comparison inquiry, remember the "rule of three." In a comparison of two items, one will naturally appear "better." Adding a third item adds ambiguity that requires the thinker to seek out more information, make more connections, and reach more nuanced conclusions.

Notice that the last step in comparison combines generating a summary of findings and generating original thoughts. Remember Goldberg's mermaid example from a previous chapter. You do not need your frontal lobes to recall a fish or a girl from memory, but when you use your frontal lobes to link those memories, you can generate a mermaid. In his example, the mermaid is likely something you have not experienced before; it is the new idea. All thinking tasks, then, could properly end with new ideas since that is what our brains can naturally do when we make associations in everyday life. As a practical illustration, the task of comparing world leaders might conclude with students creating a job description for the next head of state instead of just summarizing the information they've collected about the leaders.

Once students have learned and practiced the skill of comparison, it can be a useful tool for assessment. This is a case where a two-item comparison can be a better choice than a three-item comparison for the sake of delimiting the task to the time frame of a test. For example, a test might ask students to "compare two of the world leaders from among the many we have studied."

In the Classroom: Lesson Examples

Author Study

Susan Hensley, the contributing author of this book, worked with 3rd grade teachers to introduce the work of author Jan Brett to students. Susan commented that often class "discussions" consisted mostly of teachers telling students about setting, central messages, and characters' responses to events or challenges and then accepting restatements of the points she or he had provided.

To introduce the i5 approach, Susan started to search online for an image of Jan Brett and wound up spending nearly an hour on the author's website, which is rich with blog posts, videos, steps to drawing a hedgehog, and descriptions of more than 30 books. Susan had an i5 epiphany. Asking students to access the website of the author would be a way to address the standards *conduct a short research project to build knowledge about a topic, recall information from experiences, or gather information from print and digital sources* and *take brief notes on sources and sort evidence into provided categories.*

With the i5 in mind, Susan suggested that teachers read one of Jan Brett's stories aloud to their students but then show them how to access information from the author's website—janbrett.com—which is filled with *images* and includes opportunities to *interact* with her and her readers. The website also presents *information* about Brett's travels and how traveling inspires her work. As a class, students could generate questions they had about the author based on what they had learned from the website.

One thing students would discover is that Brett chooses a place to visit and study before she writes a children's story about that location. They planned to have the students read three more books and compare them on the bases of the setting, the characters, and the author's language styles. They also planned to have the students access the website for digital information about the author and her specific writing techniques. By comparing various books (*inquiry*), the teachers could guide the students to predict what setting the author might write about next and what types of characters would occupy the new setting.

The final task in the author study was a class collaboration calling for students to draft a letter to Jan Brett suggesting a new idea: that she write about their town and offer a locally-inspired theme and colloquial characters (*innovation*).

The i5 Reflection: The images and information Susan found while exploring Jan Brett's website were so compelling that she instantly understood the power of the i5 to encourage teachers to plan for students to benefit from the same experience. During the first lesson session, she and the teachers realized that although many of her students used digital devices for entertainment, few seemed to be aware that they could use the internet to look up an author or interact with information on a more academic level.

"The i5 reminds me to put the information, images, and interaction in the hands and minds of the students if I want them to use thinking skills," said one of the teachers. "It shifts young students from using technology for fun to using technology to learn."

Roller Coasters and Solar Panels

Ian Mulligan, a high school physics teacher, loved retelling the story (or maybe the urban legend) about the physics students at Harvard who could pass tests about formulas but were unable to fix the window blinds that hung askew. "Those could have been my students," he told us, "at least, they could have been before I started teaching thinking rather than just expecting it from my students."

In the past, Mr. Mulligan's lectures on the difference between potential and kinetic energy consisted mostly of how to apply formulas. He would give the quintessential example of the roller coaster going up and down to show the different types of energy. Students seemed to enjoy the animation of the roller coaster video and did well on the calculations. However, closer examination revealed that they were unable to imagine other examples of who would use the formulas to make or improve products or ideas. He decided that the i5 approach would target the applied understanding or students' ability to see potential and kinetic energy in real-world examples.

To begin, Mr. Mulligan showed a drawing from the 1500s, credited to da Vinci, of a trebuchet launching stones, fire, and dead animals over a castle wall. His point was that potential and kinetic energy was not new—and had been applied in odd ways over centuries. As Mr. Mulligan had done in the past, he taught the formulas and lectured about energy (*information*). This time, he asked students to search for potential and kinetic energy online, but to do it via an image search. They found examples as different as satellites in orbit, shooting arrows, and beating hearts (*images*). Mr. Mulligan set up a class chat (*interaction*) with a homework assignment where students could post *information* and ask questions or hypothesize about real-world situations in preparation for in-class discussion.

Next up was the lesson's inquiry task, set up to engage students in comparing the examples they'd gathered. After teaching the steps of comparison, Mr. Mulligan asked students to compare different products that might then be improved when applying the knowledge of potential and kinetic energy. Mr. Mulligan showed students how to search online for "thinking maps," and found many different examples of organizers suitable for various grade levels and subject areas. He found it useful to support students' working through the steps of thinking by providing a graphic organizer to compile the information about a topic.

Mr. Mulligan found that the more *images* and videos of soccer kicks, bridge designs, volcanic eruptions, and ice skating students saw to explain movement, the more technical vocabulary they sought to use in their searches and in their discussions of findings with peers (*interaction*). One student pair created a matrix (*inquiry: comparing*) of different solar panel systems. They compared the systems based on materials, layouts, positioning, and size, and used what they had learned about energy to make suggestions for improvement to the products. In the end, all the students personalized their tasks by showing the products and sharing ways that the companies should change their designs (*innovation*).

The i5 Reflection: Mr. Mulligan's "aha" in teaching physics came when he realized that one or two examples are not enough for students to understand abstract concepts well enough to generate their own ideas about them. By searching and reading online, his students engaged with varied examples; the more they viewed, the more questions they asked, and the better they began to understand the application of potential and kinetic energy. The pivot step of identifying features expanded the students' range of products to compare. Teaching comparison led them to more deeply understand how things work and how those things might be improved.

Mr. Mulligan noted that technology can provide more feedback than a single teacher can generate alone. Students can get feedback by working in pairs or groups, and by searching, they can provide self-feedback. When provided with a challenging task, students search for images and information, some may be off-base, but they learn through those missteps. Because students are online, at any moment, all of them can view the same example with a link or on a shared document. The immediacy and flexibility of using technology provides motivation that keeps even the most social adolescent focused on the goal of the lesson.

Classifying

Scientists classify living things to help explain relationships among plants and animals and make predictions; department stores classify and reclassify products to help shoppers locate products and encourage them to buy more; nutritionists classify foods to help us make healthy choices. We might classify spices in the kitchen cabinet, shoes in the closet, or tools in the shed. Often classifying, like other inquiry processes, leads to simple, yet useful discoveries. Grouping items by like characteristics and then regrouping them is a skill that helps us understand the world in which we live.

The associations we make when classifying, coupled with existing memory and emotion, allow us to decide whether to keep the information to store as memory, filter it, or even use it as a launching point for inquiry. Most important—and this is a great part about being human—the movement of this declarative knowledge, the association and re-association with prior knowledge, prompts us to transform the inputs we receive into a new understanding or ideas: something that is ours, informed by our memories and experiences. The periodic table, for example, is not a static old classifying system, but a dynamic classification that motivates scientists to search and create more elements (Kean, 2010). If that is the case, then areas other than science could provide students with similar motivation to generate new ideas. Why not classify tools in a design class, software programs, masterpieces, diseases, or words to see if the associations help students understand the topic more deeply, retain the information better, and possibly generate insights that motivate them to learn more or create a new product?

Ask yourself: What kinds of **classifying tasks** do you assign, and for what purposes? Then, with these tasks in mind, ask yourself the **i5 questions**:

1. How else could the students and I search for *information?*
2. How else could we use visual *images* and nonlinguistic representations to add meaning?
3. How could I encourage students to *interact* with others, live or through social media, to obtain and provide feedback?
4. How could I teach the *inquiry* skill—classifying—to deepen knowledge?
5. How could I plan for the students to use the application to generate *innovative* insights and products related to the lesson goals?

The Procedure

Some information we teach is already classified in a standardized way (e.g., the scientific classification in biology or titles in a genre) and we also teach classifying as a skill to understand why it is so important to know that element and animal classifications are standard. But we can teach students to classify as a thinking skill, sort and regroup items on their own, fine-tune details, clear up misconceptions, and draw insights about the topic. Whereas in a comparison, the association process is driven by making a one-to-one correspondence between (and among) items on single features, classifying is best applied when large numbers of items are grouped according to combined features. Figure 3.2 shows the steps of classifying to teach to students and incorporate into lessons.

Classifying is a skill students can use whenever there are multiple factors to consider.

FIGURE 3.2
How to Classify

The objective: Group items together based on shared traits.

Steps in the Process	Simplified Language
1. Identify multiple items to sort.	1. Name items to classify.
2. Sort the items based on a single or multiple attributes.	2. Sort the items and say why they are in a group.
3. Reorganize or regroup items.	3. Say how items could go into different groups.
4. Summarize findings to generate new ideas or products.	4. Tell what you know now (share a new idea) or could do with the information (create a new product).

The pivot step in applying classifying as an inquiry skill is Step 3, regrouping. For example, in a speech class, students might view a set of speeches and classify them according to various criteria; regrouping these speeches, they may realize that size of audience impacts the delivery. Students in a primary-grade math class assigned to group triangles might regroup them to see patterns that help them understand how they could use different triangles to measure more efficiently. In a building trade class, students could classify home repairs, and then, when the repairs are regrouped, generate insights on how to prepare an alternate budget based on costs, not time.

In the Classroom: Lesson Examples

America in Conflict

Susan worked with a team of 5th grade teachers to plan an interdisciplinary unit about conflict. *Bull Run,* a book by Paul Fleischman (1993), provides 16 monologues that give life to different perspectives about race, gender, the economy, and social tensions during the U.S. Civil War. Susan suggested that the teachers apply the i5 by focusing on the standard that asks students to "Describe how a narrator's or speaker's point of view influences how events are described." She also pointed out that because *Bull Run* has so many characters, its study would be a great opportunity to use and build classifying skills.

The teachers randomly assigned characters to students. Although everyone would take notes as they listened to online audio of the monologues, they would pay special attention to details about their assigned characters (*information*). The task required students to create a dossier for their character by gathering images and accurate related historical information online; then they formatted the information into an electronic trading card (*information, images*). Students shared the cards online so all students could view each other's character cards (*interaction*).

After teaching the steps to classifying, the teachers helped students brainstorm possible ways to group the characters. Some characters believed that joining the army to fight on front lines was important while others did not share their points of view. Students worked in teams to classify characters based on categories such as gender, geography, action taken, or an event that happened to them (*inquiry: classifying*). The classifying exercise provided time for teachers to listen in to conversations, give feedback, and offer suggestions about creatively reclassifying the characters as a way to deeply understand the conflict they studied.

After the activity, the students were asked to summarize their understanding of *Bull Run* and also comment about today's world (*innovation*). Would different people share points of view if they were different genders or race? What might make some people disagree, even if they were in similar occupations? The students were then able to transfer what they knew to more current situations.

The i5 Reflection: Planning to teach a thinking skill can change a good lesson with good materials into a great lesson where students tease out the nuances of the content. Students leave an activity like this one with a heightened awareness that those on different sides of a conflict can have very similar ideas. With access to the audio monologues and images, students could visualize the speakers and their plights; they could see the geography, the housing, and even the distance that some spoke of traveling. Although the *information* from the readings online was engaging for the student groups (*interaction*), and the *images* were revealing, the *inquiry* task of classifying and reclassifying added an element of tension that increased the students' interest in the topic of the Civil War and its impact on everyday people.

Sorting Cells

Classifying tasks are a staple of Veronica Armstrong's lessons. "Picture yourself back in biology class learning about cells," she told us. "Your teacher probably handed you that two-dimensional, black-and-white diagram of a rectangular plant cell and a round animal cell and asked you to label the parts. I want my students to understand these concepts more deeply by shifting students' role from memorizing material to being active thinkers."

Using the i5 approach, Ms. Armstrong showed students 10 electron micrographs of each cell type (*images*) from online sources. She taught students to use the Cell Image Library (cellimagelibrary.org) and the Cell-Centered Database (www.ccdb.ucsd.edu) to gather more examples (*information*), which they classified based on their knowledge of the characteristics of cells as well as organelles (*inquiry: classifying*). The benefit to using the online resources was the number of possibilities it opened; its vast stores of images could lead to all kinds of questions and understandings. Because students worked on a shared drive, Ms. Armstrong could give them real-time feedback, and students could seek feedback from peers as well (*interaction*).

"My goal is to challenge students to go beyond just labeling and explaining the parts of cells to understanding the functions of the parts, so that they can generate new ideas or deduce functions that may not yet be confirmed (*innovation*)," Ms. Armstrong explained. "Changing my old task to a classifying task worked since the online resource offers almost unlimited material. This *inquiry* gave students many more opportunities to genuinely ask questions about types of cells and functions rather than asking me for directions about how to fill in the old paper organizer."

The i5 Reflection: Before digital technology was commonplace in the classroom, it was customary for students to view a limited number of slides while sharing a limited number of microscopes; now students can view dozens of common and unusual images online. Online databases provide more information than students can find in classroom sets of print materials and provide links to other sites where students can find answers to questions that arise as they engage in thinking tasks. This lesson illustrates how using technology to access resources can transform science tasks, and how the use of common performance space (a shared drive) can facilitate timely feedback from both teacher and peers.

Creating Analogies

Analogies are ways that we make the unfamiliar familiar and that make new information easier to understand. Recalling a past situation provides concrete images, and we are able to connect new information to existing understandings. With this experience or knowledge now enlisted, we can think more clearly about a new situation. It's remarkable how adept we are at recognizing highly diverse domains that have only the slightest thread of a common connection: the leader is a rhino, dinner smells like heaven, the melody is like the tides, and so on.

In *Shortcut: How Analogies Reveal Connections, Spark Innovation, and Sell Our Greatest Ideas* (2015), John Pollack writes about great figures in business who famously used analogies to create empires—for example, Steve Jobs of Apple. In the 1980s, Jobs gave a speech about what Apple was going to do to sell computers. He talked about a study that he had read in *Scientific American* focused on comparing the speeds of animals. Interestingly, he said, while others collected data about the animals, one scientist thought to test a human on a bicycle; the human on the bike vaulted into the top spot of the standings, achieving the highest speed while expending the least amount of energy. Humans, Jobs noted, are toolmakers; they could augment an inherent ability with a tool. The tool he was focused on, he said, would be the computer—the bicycle for the mind.

Pollack states that analogies may often go unnoticed, but they are nonetheless arguments, albeit "arguments that, like icebergs, conceal most of their mass and power beneath the surface. In many arguments, whoever has the best analogy wins" (pp. xiv–xv). Teachers can teach students to go below the surface by teaching them the steps for and practicing mining information by creating their own analogies.

Ask yourself: What kinds of **analogy-creation tasks** do you assign, and for what purposes? Then, with these tasks in mind, ask yourself the **i5 questions**:

1. How else could the students and I search for *information?*
2. How else could we use visual *images* and nonlinguistic representations to add meaning?
3. How could I encourage students to *interact* with others, live or through social media, to obtain and provide feedback?
4. How could I teach the *inquiry* skill—creating analogies—to deepen knowledge?
5. How could I plan for the students to use the application to generate *innovative* insights and products related to the lesson goals?

The Procedure

Creating an analogy involves noting and using the relationship between two similar situations to produce a deeper understanding. Analogies can be a word, a metaphor or a simile, or an entire story line.

Journalists use them frequently and often deftly. You might read a news story where, either explicitly or implicitly, the journalist describes someone as an ogre or a situation as a Cinderella story. These remind you of fairy tales that provide you with insight into a predictable ending. The analogy guides you to speculate well before the writer states what actually happened.

Teachers have many opportunities to teach students to strengthen this inquiry skill in any grade level or subject; it is likely all students will have some common memories, and that is a solid start. Figure 3.3 shows the steps of creating analogies.

FIGURE 3.3
How to Create Analogies

The objective: Identify a relationship or pattern between a known and an unknown situation.

Steps in the Process	Simplified Language
1. Identify an event or topic that is difficult to understand.	1. Tell about a topic that is hard to understand.
2. Identify a familiar situation describing the steps or the parts in general terms.	2. Explain a familiar story or experience in your own words.
3. Explain the new event or topic using the familiar situation to guide the narrative.	3. Tell how each part of what you know works, so you can explain the new topic.
4. Summarize understandings and generate insights about the new event or topic.	4. Tell what you know now (share a new idea) or could do with the information (create a new product).

Because analogies often involve engaging an audience, the pivot step that prompts thinking is finding the right familiar situation to reveal the iceberg below. As a caution, we remember a teacher telling us that when teaching 7th graders, she referred to the characters in the junior literature book as Macbeth-like, hoping to excite the students and generate discussion. Instead, the students fell silent. Since they were not familiar with *Macbeth* (as they might have been with a *Romeo and*

Juliet reference), they could not follow through with the analogy. "Double, double toil and trouble"—literally!

If you identify the right familiar story or experience, then you can methodically connect each part of a familiar concept to a new one. That marks the moment when you use what you know to actively process the new situation; you begin to think. When we teach to students to make analogies when they encounter new information, we equip them to intentionally connect it to prior knowledge to generate new and deeper understandings. What makes analogies creative is that you can also add twists or turns to the relationships, generating surprises in the result. For example, when reporting about a politician in the news using "The Emperor's New Clothes" as the familiar sequence of events, the journalist may surprise the reader by divulging that at the end of the day, that politician was really the little boy, and not the emperor.

When we work with teachers to plan lessons to teach thinking skills, we use an analogy. We describe the frontal lobes as the brain's Swiss Army knife. The knife has blades, a screwdriver, a can opener, and other versatile tools stowed in the handle with a pivot mechanism; the frontal lobes involve the use of thinking skills. Different tools work for different situations. When you need to cut a piece of rope, you use a blade or the scissors. For planning instruction, you may choose to address the situation by solving it as a problem, or you may choose to analyze perspectives. The Swiss Army analogy allows us to view thinking skills as specific tools, some of which work better than others given the subject area. It should also encourage teachers to avoid "binging" on skills and try different thinking skills in lessons.

In the Classroom: Lesson Examples

The Ecosystem and the Government

Carla Hemmers teaches 3rd graders. In the beginning of the school year, her students learned about habitats and different ecosystems; they learned about interdependence. To deepen understanding, they gathered online *information* and *images* of forests, tundra, deserts, and so on and used Glogster (http://edu.glogster.com) to create interactive multimedia posters that show how interdependence works in ecosystems.

In the second term, Ms. Hemmers's students studied the functions of the local government in social studies class. Because of the interdependence of people in government, she saw this lesson as an opportunity to teach analogy (*inquiry*). Following the steps in the process, the class revisited the familiar concept of ecosystems. Then they identified the new situation as people and government and systematically used information from the familiar to learn how parts of the town government work together. Ms. Hemmers was surprised when the students asked questions extending the analogy to state and national government systems. As the students worked through the analogy, they found they needed to go online to find *information* and *images* that would provide an explanation. The students used Ed.VoiceThread, a collaborative presentation app (http://voicethread.com/products/k12/) to showcase their statements that began with this prompt: "____________ is to a government like ____________ is to an ecosystem" (*innovation*). Other students could ask questions or clarify their analogies (*interaction*). In summarizing their work, students could see how schools and households might also be said to have the same traits as both the ecosystem and government, because they also were composed of people who depended on one another.

The i5 Reflection: Ms. Hemmers was amazed at how 3rd graders could use information from an earlier science lesson to transfer to the topic of governments. She also said that she expected her students to produce similar examples, but the students seemed motivated to create something unique, spurred on by having access to one another's work. The online digital conversation and interactions with other students enriched their discussions, but it also allowed Ms. Hemmers time to formatively assess the students as they worked on their analogies, clarifying the content and correcting any misunderstandings.

The Brain Is Not Like a Computer

When a PLT (professional learning team) in Psychology and Humanities at a secondary school asked us to help them apply the i5 to teaching about the human cognitive system, or how the brain works, it led to a slight adjustment in their lessons. Here's a look at what we planned.

First, teachers in their own classes asked students to search online, in pairs, for images of computers and generate a list showing five parts and functions of a computers (*images, information, interaction*). Then, they showed a 30-second video of a busy hotel lobby, in which the camera panned up to show a glass elevator with people heading up to their rooms. The next slide featured a quotation from Massachusetts Institute of Technology memory expert Suzanne Corkin: "Our brains are like hotels with eclectic arrays of guests—homes to different kinds of memory, each of which occupies its own suite of rooms" (2013, p. 51). A few minutes later, they presented a slide showing a photo of an orchestra and quoted neuroscientist Elkhonon Goldberg (2009) describing the brain's prefrontal cortex as the conductor: Humans learn by making connections between and among pieces of information. The prefrontal cortex is the brain boss, or the conductor of the orchestra of learning.

The teachers posed a question to the class: *Which best depicts the structure and function of the human brain—a computer, a hotel, or an orchestra?* The ultimate task, they explained, would be for students to build their own analogy (*innovation*) to describe the workings of the brain as they studied the structure and function of the human cognitive system. They could use *information* and *images* they found online to expand their analogies, ranging from ant colonies to subway systems. This allowed them to include details beyond what was presented to them in class, and they created slide decks that they shared on the class website. Students also provided feedback on each other's assignments online by asking questions related to the cognitive parts or functions as shown in the analogies (*interaction*).

The i5 Reflection: In the past, these teachers would have provided one analogy to the students. The i5 approach's advocacy of including inquiry skill instruction to generate new iterations or uses of knowledge gave them a framework to teach students to be creative, but also accurate, when explaining brain functions. Updating their lesson plans to enlist technology made this possible, as it was the technology that gave students access to the additional imagery and information that fueled their creativity, and their analogies.

Summary

The skills of association empower students to transform declarative knowledge presented to them into deeper and more personal understanding. To be more specific, two types of learning happen when students associate. First, they connect new ideas they're encountering in the lesson to established knowledge and prior experiences, increasing the likelihood they'll retain new information. Second, students become more *efficient* at making these connections, setting themselves up to be increasingly adept thinkers who will likely generate productive ideas and discoveries. Association is fundamental to how we function in our daily lives, so to address it in our study of inquiry skills is a logical starting point.

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