Chapter 9

GENERATING & TESTING HYPOTHESES

Mrs. Justice designed a multidisciplinary unit around Goldilocks and the Three Bears *that would help her primary students learn concepts in many different academic areas. One lesson involved helping students learn the skills of scientific observation.*

She began the lesson by reading Goldilocks and the Three Bears. *She then read this poem:*

"Peas porridge hot
Peas porridge cold
Peas porridge in the pot
Nine days old."

With students' help, Mrs. Justice made a bowl of oatmeal. After it cooled, she covered it with plastic. She then asked students to predict what the oatmeal would look like after sitting on the classroom counter for nine days, like the porridge in the poem. She wrote each student's prediction on a chart on the board. Some students thought the oatmeal would dry up; others thought it would evaporate; others thought it would get moldy and smell bad.

Each day students observed what the oatmeal looked and smelled like. They then colored pictures in a journal and made notes about what they observed. For example, students wrote whether there was water on the plastic wrap, used crayons to indicate the color of the oatmeal, and wrote whether the oatmeal looked the same as it had the day before. On the ninth day, students compared their original predictions to what the oatmeal really looked like.

The lesson Mrs. Justice designed gave her students an opportunity to experience what it might be like to be a scientist and involved them in a highly complex form of thinking — generating hypotheses and then testing these hypotheses.

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Generating and testing hypotheses involves applying knowledge. For example, consider a student who watches a demonstration of how air flows over the wing of an airplane. After watching the demonstration, he applies what he has learned to hypothesize that changing the shape of the wing in a specific way will have a specific effect on the flow of air, designs a wing with the desired shape, and then tests his conjecture.

1. Use a Variety of Structured Tasks to Guide Students Through the Process of Generating and Testing Hypotheses.
(See Illustrations 1.1–1.6)

Many people associate generating and testing hypotheses with the scientific method. However, this strategy can be used across all disciplines. In this section we describe six types of tasks that require students to generate and test hypotheses: systems analysis tasks, problem-solving tasks, historical investigation tasks, invention tasks, experimental inquiry tasks, and decision-making tasks.

Systems Analysis

Across the disciplines, students have opportunities to study systems: computer network systems, the highway system, ecosystems, government systems, weather systems. To analyze these systems, teachers can ask students to generate and test hypotheses about what might happen if a part of the system changed. Teachers might guide students' work using the following general framework:

1. Explain the purpose of the system, the parts of the system, and the function of each part.
2. Describe how the parts affect one another.
3. Identify a part of the system, describe a change in that part, and then hypothesize what might happen as a result of this change.
4. When possible, test your hypothesis by actually changing the part. Or "test" the hypothesis by considering the effects of the change on the system.

Problem Solving

Solving a problem requires students to understand obstacles and constraints. They also must generate and test hypotheses about possible solutions. Teachers might guide students' work using the following general framework:

1. Identify the goal you are trying to accomplish.
2. Describe the barriers or constraints that are preventing you from achieving your goal — what is creating the problem?
3. Identify different solutions for overcoming the barriers or constraints and hypothesize which solution is likely to work.
4. Try your solution — either in reality or through a simulation.
5. Explain whether your hypothesis was correct. Determine if you want to test another hypothesis using a different solution.

Historical Investigation

Historical investigation involves examining defensible scenarios for a past event about which there is no general agreement. To engage in historical investigation, students must use their understanding of the past situation and key players in the event to generate a hypothesis. Testing the hypothesis requires collecting and analyzing information to determine if the evidence supports it. Teachers can adjust the complexity level of an investigation for younger students, as exemplified by Illustration 1.4. Teachers might guide students' work using the following general framework:

1. Clearly describe the historical event to be examined.
2. Identify what people know or agree about and what people do not know or disagree about.
3 Based on what you understand about the situation, develop a possible explanation or a resolution of the disagreement.
4. Seek out and analyze evidence to determine if your explanation or resolution is plausible.

Invention

People invent products or processes to fulfill specific needs. The invention process involves hypothesizing what might work, developing the idea, and testing the invention. This process might require developing several hypotheses and conducting multiple tests before achieving an effective result. Teachers might guide students' work using the following general framework:

1. Describe a situation you want to improve or a need you want to respond to.
2. Identify specific standards for the invention that would improve the situation or meet the need.
3. Brainstorm ideas, and hypothesize the likelihood that each will work.
4. If your hypothesis suggests that a specific idea might work, begin to draft, sketch, and actually create the invention.
5. Develop your invention to the point that you can test your hypothesis.
6. If necessary, revise your invention until it reaches the standards you have set.

Experimental Inquiry

Although many educators commonly associate the process of experimental inquiry with generating and testing hypotheses in science, this strategy can be used across the disciplines to help students use knowledge meaningfully. The same process that drives inquiry in science classes can be used to explain observations, generate explanations, and make and test predictions. Teachers might guide students' work using the following general framework:

1. Observe something of interest to you and describe what you have observed.
2. Apply specific theories or rules to explain what you have observed.
3. Based on your explanation, generate a hypothesis to predict what might happen if you apply the theories or rules to what you observed or to a situation related to what you observed.
4. Set up an experiment or engage in an activity to test your hypothesis.
5. Explain the results of your experiment or activity. Decide if your hypothesis was correct. Also decide whether you need to conduct additional experiments or activities or generate and test an alternative hypothesis.

Decision Making

Generating and testing hypotheses may not seem related to making a decision, but students can examine hypothetical situations using a structured decision-making process. For example, when choosing the best or worst representative of a specific category, such as the worst movie of the 1990s, students will likely make a prediction. A structured decision-making framework requires them to use a broad range of knowledge to develop criteria and test their predictions against these criteria. Teachers might guide students' work using the following general framework:

1. Describe the decision you are making and the alternatives you are considering.
2. Identify the criteria that will influence the selection and indicate the relative importance of the criteria by assigning an importance score, such as 1, 2, 3, or 4.
3. Using a designated scale, such as 1–4, rate each alternative to indicate the extent to which each alternative meets each criterion.
4. For each alternative, multiply the importance score and the rating and then add the products to assign a score for the alternative.
5. Examine the scores to determine the alternative with the highest score.
6. Based on your reaction to the selected alternative, determine if you need to change any importance scores or add or drop criteria.

2. Ask Students to Explain Their Hypotheses and Conclusions.
(See Illustration 2)

The process of explaining their thinking helps students enhance their understanding of the concepts they are using. To facilitate this process, teachers can design assignments that require students to explain how they generated their hypotheses and describe what they learned as they tested them, as Illustration 2 exemplifies. Teachers might use a variety of strategies, such as the following:

- Provide students with a "results template" that highlights areas where students will be required to explain their work and describe what they learned.

- Give students (especially younger students) sentence stems to prompt their thinking about the process, for example, "I think if I change _________, then _________ will happen"; "While doing this task, I learned _______."

- Ask students to submit an audio tape that describes the steps they used to generate and test a hypothesis and what they learned in the process.

- Work with students to develop a rubric that establishes criteria for evaluating the clarity and thoroughness of explanations as well as the degree to which the explanations are supported by evidence.

- At school events, such as parent-teacher conference days, provide opportunities for parents and others to ask students to explain their thinking.

ILLUSTRATION 1.1: STRUCTURED TASK *systems analysis*

Mrs. Ollinger had been teaching her third graders about simple food chains and food webs, but she wasn't sure they were seeing how all the pieces connected. She decided to talk to her class about food chains and webs as systems.

After she explained the purpose of a food web, she called on students to identify the parts of a specific food web and describe the function of each part. Students described a food web in a forest that included squirrels, birds, rabbits, snakes, deer mice, owls, white-tailed deer, black bears, spruce, fir, aspen trees, berries, and various grasses. Students drew diagrams and pictures to show how different parts affected one another.

For homework, Mrs. Ollinger asked students to choose a part of the food web, describe a change in that part, and make a prediction about what might happen to the rest of the web. Although students could not actually change a part of the system, the next day they "tested" their hypotheses by explaining them and the conclusions they had drawn.

Dan wondered what would happen if the owls became extinct. He hypothesized that if the owls disappeared, the population of deer mice and rabbits would grow a lot because there would not be as many predators. Another student pointed out that the number of snakes might also increase, which might in turn help reduce the number of rabbits and deer mice. In this way, students described their hypotheses, explained their conclusions, and extended their understanding of food chains as systems.

ILLUSTRATION 1.2: STRUCTURED TASK *problem solving*

Mr. Deshler's sixth graders were studying how political, religious, and social institutions affected family and community life in colonial America. He wanted them to gain an in-depth understanding of what people faced when they came to the English colonies. To focus the rest of the unit, he presented them with the following scenario:

> You are a 25-year old woman on a ship headed to the British colonies. Your husband died 6 days into the journey, leaving you on your own. You are devastated by your loss but decide you want to live in the new colonies as an independent woman. How will you achieve this goal?

Mr. Deshler and his students completed a character sketch of the woman on the ship by giving her a name and filling in details: how much money she had, what her skills were, etc. They decided where the ship would land and spent the next week identifying the barriers and constraints she would face, describing different solutions, and testing these hypotheses based on what they were learning about colonial America.

ILLUSTRATION 1.3: STRUCTURED TASK *historical investigation*
COMPLEX

While teaching her world history students about the Great Depression, Mrs. Belvin seized the opportunity to engage her students in an investigation: What caused the Great Depression?

The class discussed events leading up to the Depression. In addition, Mrs. Belvin presented some of the commonly held views about the cause of the Depression, including the decline in investment spending, the high tariff passed during the Hoover administration, and poor monetary policy. Although she did not expect her students to resolve a disagreement that economic historians have debated for years, Mrs. Belvin thought the investigation would help her students gain an in-depth understanding of the historical issues and economic concepts related to the Great Depression.

Students created possible explanations based on their understanding of the economic elements and key players of the time. Students then collected and analyzed information to determine if the evidence supported their hypothesis. When they shared their findings, students realized that the evidence could support more than one hypothesis. This discovery taught them an important lesson about how people interpret history — sometimes more than one plausible explanation or interpretation exists.

ILLUSTRATION 1.4: STRUCTURED TASK *historical investigation*
LESS COMPLEX *(typically for younger students)*

Ms. Schoch's fourth graders were learning research skills. Ms. Schoch wanted her students to think about what people commonly know about historical figures. She asked them to pick one of their favorite people from history and research a famous story about that person.

One student wanted to find out if George Washington really chopped down the cherry tree. Another student wanted to know why Amelia Earhart just disappeared. As they were doing their research, students learned that some widely shared stories are not true at all and that sometimes history books do not have all the answers. These discoveries gave Ms. Schoch and her students a chance to discuss history in a new light. Her students learned that often there is more to a story than what one first hears.

ILLUSTRATION 1.5: STRUCTURED TASK *invention*

Several students in Mr. Eversole's small engines class were serious snowmobile riders. Concerned about the recent ban of snowmobiles from various parks and national forest lands, they decided to build a cleaner, quieter snowmobile for their final team project.

Students consulted regulations on several government Web sites to help them set standards for acceptable emissions and noise levels. Next, using what they had learned throughout the year, students generated hypotheses about engine redesign, alternative fuels, and materials for noise reduction. Keith suggested they design a four-stroke engine, but other team members thought it would be too heavy and have a sluggish throttle response.

Finally, students decided to refine a two-stroke engine and reduce carbon monoxide emissions. As they drafted the model for the new engine, the team members checked in periodically with Mr. Eversole to ask questions and receive feedback. They constructed their invention in stages, testing and revising the engine until they were happy with the results before moving on to other design features of the snowmobile. When they were finished, the students explained how their snowmobile was quieter than existing models and how it met emission and noise level standards.

ILLUSTRATION 1.6: STRUCTURED TASK *experimental inquiry*

Chantelle had been a "Navy brat" her whole life. By the time she was in eighth grade, she had grown accustomed to her father's schedule — 12 months at home, six months away.

One day in her health and life skills class, the teacher talked about test-taking skills and how "outside" factors could influence a student's performance. For example, if a student had a cold, she might not perform as well on a test as she would if she didn't have a cold. This idea made Chantelle think about how her father's long absence might affect her school work. She knew that sometimes when her father was gone, she didn't know where he was and worried about his safety. Was this distraction one of those "outside factors"?

Chantelle hypothesized that the long absence of a child's father or mother would have a negative effect on the child's performance in school. In order to test her hypothesis, she worked with her teacher to create a questionnaire and collect some data. Chantelle interviewed students and their parents who served in the military. She also talked to teachers who had taught children from military families to see if they had any insights. Her teacher helped her gather some student achievement data from published studies so Chantelle could look for related patterns. Chantelle was surprised to find that she could not come to a definite conclusion about the effects of a parent's long absence on student performance. In some cases, her hypothesis was correct, but in others it was not. She concluded that more study was needed in this area.

ILLUSTRATION 1.7: STRUCTURED TASK *decision making*

Mrs. Switzer's primary students had been studying different characteristics of music and how music affects people's moods. To help her students put it all together, Mrs. Switzer asked them to help her friend, Dr. Watson, figure out what type of music to play in her waiting room.

Mrs. Switzer explained that Dr. Watson was a family doctor who saw all kinds of patients, including very young children, pregnant women, and older patients. Mrs. Switzer drew a decision-making matrix on the board and filled in the alternatives the class wanted to consider: jazz, classical, contemporary pop, and "oldies."

As a large group, the class identified the characteristics of music that would influence their decision. They chose "smooth rhythm," "soothing melody," and "steady tempo." Mrs. Switzer explained that they would rate each type of music to show how it matched each characteristic. She described the rating scale in terms students could understand: 4 meant "a whole lot," 3 meant "some," 2 meant "a little bit," and 1 meant "barely at all." Mrs. Switzer walked them through the first couple of characteristics for jazz and then asked students to work individually.

After the students finished filling in the matrix, she showed them how to add up the numbers to find out which alternative had the highest score. (Because of their age, she automatically assigned each criterion an importance score of 1, so that multiplication was not required.) Students checked each other's math, and then the class discussed the choices they made.

Decision-Making Matrix

	Alternatives			
Criteria	Jazz	Classical	Contemporary Pop	"Oldies"
smooth rhythm	1			
soothing melody	2			
steady tempo				
Totals				

ILLUSTRATION 2: EXPLAIN HYPOTHESES & CONCLUSIONS *"small engines" class*

Mr. Eversole, the small engines teacher, was very pleased with the progress his snowmobile team was making on their project. However, he really wished students would concentrate more on explaining their thinking. To encourage this behavior, he provided the team with a "thinking sheet" to complete at regular intervals during the invention process.

Our hypothesis: ____

____

____

We think this idea will work because

____

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After we tried this idea, we found

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We made modifications ____Yes ____No

After we made modifications, we found

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THEORY AND RESEARCH IN BRIEF • • •
Generating and testing hypotheses

Findings from some of the studies that have synthesized research on generating and testing hypotheses are reported in Table 9.1. Notice that some of the studies listed in Table 9.1 distinguish between strategies that are more *deductive* in nature and those that are more *inductive*. Using the figures in Table 9.1, we can compute an average (weighted) effect size for techniques that are more deductive in nature of .60 and an average (weighted) effect size for techniques that are more inductive in nature of .39. Given this difference, it is useful to consider the nature of deductive versus inductive techniques.

Table 9.1: Research Results for Generating and Testing Hypotheses

Synthesis Study	Focus	No. of Effect Sizes	Ave. Effect Size	Percentile Gain[a]
Hattie, Biggs, & Purdie, 1996	General effects of generating & testing hypotheses	2	.79	28
Tamir, 1985	Deductive techniques	13	.27	11
Lott, 1983	Deductive techniques	18	.02	1
	Inductive techniques	4	.10	4
Ross, 1988	Deductive techniques	65	.83	30
	Inductive techniques	39	.48	19
El-Nemr, 1980	Inductive techniques	250	.38	15
Sweitzer & Anderson, 1983	Inductive techniques	19	.43	17
Walberg, 1999	Inductive techniques	38	.41	16

[a]These are the maximum percentile gains possible for students currently at the 50th percentile.

Deductive thinking is commonly thought of as the process of using a general rule to make a prediction about a future action or event (see Johnson-Laird, 1983). For example, while beginning to read a story about a particular wolf, you will naturally access some of the generalizations you have about wolves from your permanent memory. If one of those generalizations is “wolves run in packs and are highly social,” then you will predict that the story will contain episodes about the interaction of the individual wolf with other wolves that are members of a pack.

It is worth noting that thinking in real life is probably never purely inductive or deductive. Rather, scholars assert that reasoning is often more “messy” and nonlinear than it is commonly believed to be (Eco, 1976, 1979, 1984; Medawar, 1967; Percy, 1975; Deely, 1982). Many philosophers have advanced the concept of *retroduction* as a more fruitful approach to understanding the nature of inferential thinking. Retroduction is the act of generating and shaping an idea based on one or more cases. Sometimes inferences made during this process are more inductive in nature; sometimes they are more deductive in nature.

Inductive thinking is thought of as the process of drawing new conclusions based on information we know or are presented with (see Holland, Holyoak, Nisbett, & Thagard, 1986). For example, if you are reading an account of how a particular bear behaved when observed by a scientist, you would induce that the behaviors observed multiple times by the scientist are behaviors the bear habitually engages in or even behaviors that *all* bears habitually engage in.

Inductive techniques are those that require students to first discover the principles from which hypotheses are generated. To illustrate using the example of air flow, a teacher would be using an *inductive* approach if she had students first discover principles about air flow and then generate hypotheses based on these discovered principles. However, a teacher would be using a *deductive* approach if she first presented students with a principle of air flow such as the Bernoulli theorem. With this knowledge as a basis, she would then ask students to generate and test hypotheses based on the principles they have been taught.

The process of generating and testing hypotheses is not limited to physical phenomena, although we generally think of generating and testing hypotheses about the physical world. For example, people discover or are taught principles that relate to phenomena like air flow and then use those principles to make and test predictions. However, the same process can be applied to psychological phenomena. For example, based on observations about how people relate to specific types of visual stimuli, someone might generate and test a hypothesis about the effects of a specific type of advertisement.