REASONING (9E)

Some aspects of reasoning have clear logical rules; others have only guidelines, and still others have almost unlimited room for creativity. While it is important for students to understand the nature of logic, it is even more important that they learn how to use logic and evidence in making valid, persuasive arguments and in judging the arguments of others.

The map is organized around four strands—*use of deductive logic in reasoning, use of evidence in reasoning, use of inductive logic in reasoning,* and *use of analogies in reasoning*. In the elementary grades, the focus is on backing up claims with reasons. In middle school, the emphasis is on examples of flaws in reasoning. High school culminates with criteria for judging the quality of reasoning.

Ideas on this map draw on and contribute to skills on the **COMMUNICATION SKILLS** and **DETECTING FLAWS IN ARGUMENTS** maps.

NOTES

Several benchmarks on this map have been revised to either clarify their intent or to improve the coherence of the strands. For example, in the *use of inductive logic in reasoning* strand, the phrase "general rule" was replaced in several benchmarks with the more familiar term "generalization." At the high-school level in this strand, the new benchmark "A failure to find an exception to a generalization…increases the confidence in the accuracy of the generalization" summarizes the use of inductive reasoning.

The new 9-12 benchmark "A sound argument should have both true statements and valid connections among them…" synthesizes ideas about logic and its use and misuse. The term "formal logic" in this benchmark is meant to distinguish between logical arguments that use a strict set of rules in making an argument from those that do not. It is not meant to suggest that an argument is illogical just because the methods of reasoning used in an argument do not adhere to a strict set of rules.

The appearance on this map of many benchmarks dealing with critical response skills highlights the intimate relationship between knowledge about reasoning and the ability to analyze the logic of an argument.

RESEARCH IN *BENCHMARKS*

Students of all ages show a tendency to uncritically infer cause from correlation (Kuhn et al., 1988; Kuhn, 1992). Some students think even a single co-occurrence of antecedent and outcome is always sufficient to infer causality. Rarely do middle-school students realize the indeterminacy of single instances, although high-school students may readily realize it. Despite that, as covariant data accumulate, even high-school students will infer a causal relation based on correlations (Kuhn et al., 1988; Zimmerman, 2000). Further, students of all ages will make a causal inference even when no variation occurs in one of the variables (Kuhn et al., 1988).

Students seem to make valid judgments about situations in which variables have an effect on the outcome earlier than in situations in which variables have no effect on the outcome, or in situations in which, given the current evidence, it is not possible to decide about a variable's role (Schauble, 1996; Kanari & Millar, 2004). Faced with inconclusive data, students may draw conclusions in line with their predictions (Kanari & Millar, 2004). Faced with no correlation of antecedent and outcome, 6th-graders only rarely conclude that the variable has no effect on the outcome (Kuhn et al., 1988). Ninth-graders draw such conclusions more often. A basic problem appears to be understanding the distinction between a variable making no difference and a variable that is correlated with the outcome in the opposite way than the students initially conceived (Kuhn et al., 1988). Another issue is that students are often not aware that all measurements are inevitably subject to uncertainty (or error) and that two measurements of a quantity that has not actually altered are therefore likely to differ (Kanari & Millar, 2004).

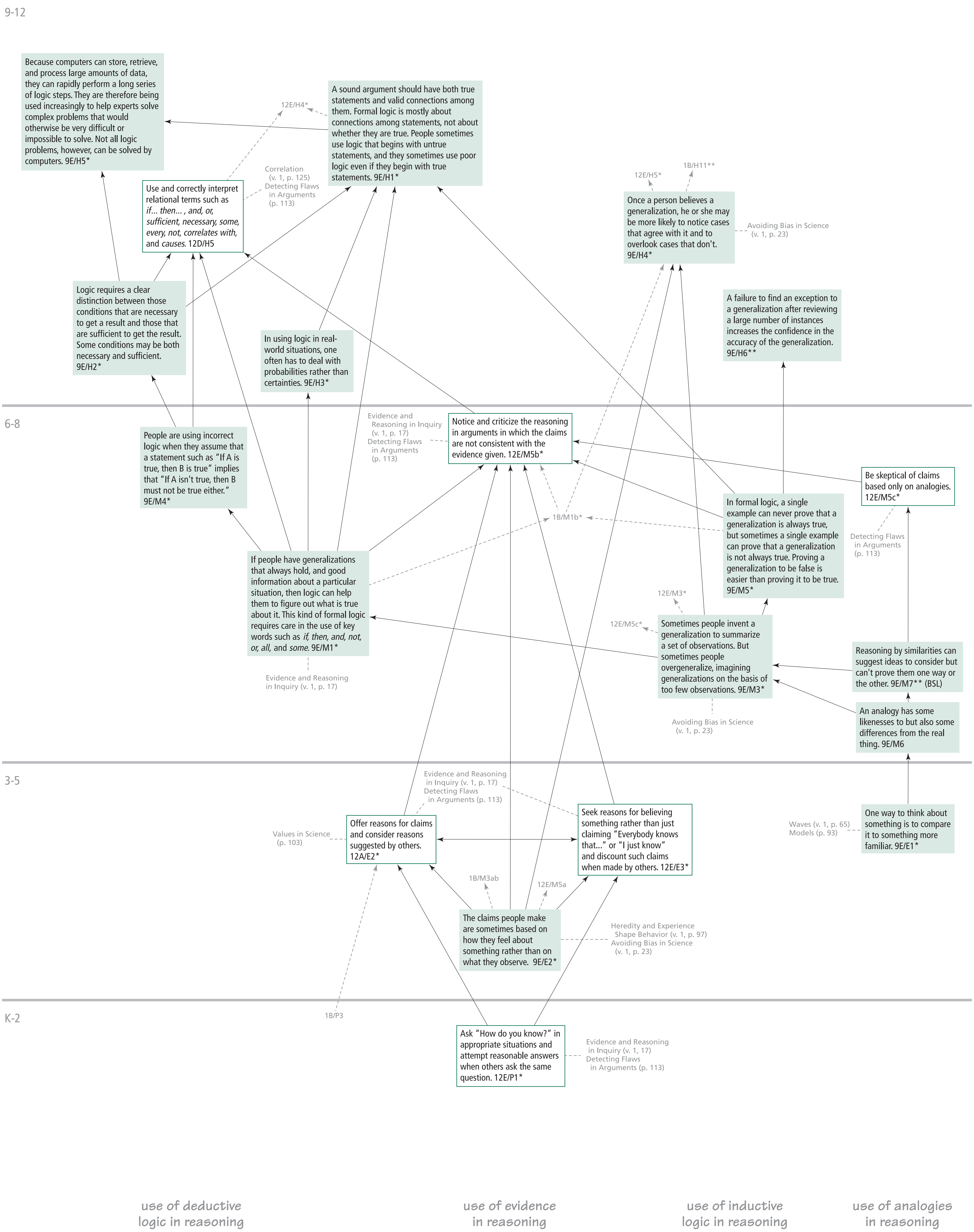
A challenge for students of all ages is to generate and interpret evidence that is inconsistent with their prior beliefs (Schauble, 1996). When data are at odds with students' prior beliefs, experiences, or predictions, students may draw conclusions in line with their prior beliefs or predictions (if their prediction is based on some underlying model of the phenomenon involved) (Amsel & Brock, 1996; Millar & Lubben, 1996). Changing beliefs in response to anomalous data may be impeded primarily because students do not make the correct observations (because of their prior belief) rather than because students ignore, distort, discount the observations, or claim that the observations do not hold in other cases (Chinn & Malhotra, 2002).

Students of all ages tend to consider the effect of only a single quantity on another single quantity (Viennot, 2001). Even in multivariable situations, students tend to consider only one factor as possibly influencing the situation, and as a consequence, may overlook other possible influential factors (Driver et al., 1996). Similarly, students have trouble explaining outcomes that are the additive product of two individual variables and may fluctuate from one variable to another trying to explain which single variable produced the outcome (Kuhn, Black, Keselman, & Kaplan, 2000).

Most high-school students will accept arguments based on inadequate sample size, accept causality from contiguous events, and accept conclusions based on statistically insignificant differences (Jungwirth & Dreyfus, 1990, 1992; Jungwirth, 1987). More students can recognize these inadequacies in arguments after prompting (for example, after being told that the conclusions drawn from the data were invalid and asked to state why) (Jungwirth & Dreyfus, 1992; Jungwirth, 1987).

When constructing or evaluating arguments, the following problems appear in student reasoning: problems with validity of arguments, a naïve conception of argument structure, inappropriate effects of core beliefs on argumentation, inadequate sampling of evidence, and altering the representation of argument and evidence (Driver et al., 2000; Zeidler, 1997).

See **DETECTING FLAWS IN ARGUMENTS** for additional research.


9-12
Because computers can store, retrieve, and process large amounts of data, they can rapidly perform a long series of logic steps. They are therefore being used increasingly to help experts solve complex problems that would otherwise be very difficult or impossible to solve. Not all logic problems, however, can be solved by computers. 9E/H5*
12E/H4*
A sound argument should have both true statements and valid connections among them. Formal logic is mostly about connections among statements, not about whether they are true. People sometimes use logic that begins with untrue statements, and they sometimes use poor logic even if they begin with true statements. 9E/H1*
Correlation (v. 1, p. 125)
Detecting Flaws in Arguments (p. 113)
Use and correctly interpret relational terms such as *if… then… , and, or, sufficient, necessary, some, every, not, correlates with,* and *causes.* 12D/H5
12E/H5*
1B/H11**
Once a person believes a generalization, he or she may be more likely to notice cases that agree with it and to overlook cases that don't. 9E/H4*
Avoiding Bias in Science (v. 1, p. 23)
Logic requires a clear distinction between those conditions that are necessary to get a result and those that are sufficient to get the result. Some conditions may be both necessary and sufficient. 9E/H2*
In using logic in real-world situations, one often has to deal with probabilities rather than certainties. 9E/H3*
A failure to find an exception to a generalization after reviewing a large number of instances increases the confidence in the accuracy of the generalization. 9E/H6**
6-8
People are using incorrect logic when they assume that a statement such as "If A is true, then B is true" implies that "If A isn't true, then B must not be true either." 9E/M4*
Evidence and Reasoning in Inquiry (v. 1, p. 17)
Detecting Flaws in Arguments (p. 113)
Notice and criticize the reasoning in arguments in which the claims are not consistent with the evidence given. 12E/M5b*
Be skeptical of claims based only on analogies. 12E/M5c*
1B/M1b*
In formal logic, a single example can never prove that a generalization is always true, but sometimes a single example can prove that a generalization is not always true. Proving a generalization to be false is easier than proving it to be true. 9E/M5*
Detecting Flaws in Arguments (p. 113)
If people have generalizations that always hold, and good information about a particular situation, then logic can help them to figure out what is true about it. This kind of formal logic requires care in the use of key words such as *if, then, and, not, or, all,* and *some.* 9E/M1*
12E/M3*
12E/M5c*
Sometimes people invent a generalization to summarize a set of observations. But sometimes people overgeneralize, imagining generalizations on the basis of too few observations. 9E/M3*
Reasoning by similarities can suggest ideas to consider but can't prove them one way or the other. 9E/M7** (BSL)
An analogy has some likenesses to but also some differences from the real thing. 9E/M6
Evidence and Reasoning in Inquiry (v. 1, p. 17)
Avoiding Bias in Science (v. 1, p. 23)
3-5
Evidence and Reasoning in Inquiry (v. 1, p. 17)
Detecting Flaws in Arguments (p. 113)
Values in Science (p. 103)
Offer reasons for claims and consider reasons suggested by others. 12A/E2*
Seek reasons for believing something rather than just claiming "Everybody knows that…" or "I just know" and discount such claims when made by others. 12E/E3*
Waves (v. 1, p. 65)
Models (p. 93)
One way to think about something is to compare it to something more familiar. 9E/E1*
1B/M3ab
12E/M5a
The claims people make are sometimes based on how they feel about something rather than what they observe. 9E/E2*
Heredity and Experience Shape Behavior (v. 1, p. 97)
Avoiding Bias in Science (v. 1, p. 23)
K-2
1B/P3
Ask "How do you know?" in appropriate situations and attempt reasonable answers when others ask the same question. 12E/P1*
Evidence and Reasoning in Inquiry (v. 1, 17)
Detecting Flaws in Arguments (p. 113)
use of deductive logic in reasoning
use of evidence in reasoning
use of inductive logic in reasoning
use of analogies in reasoning