

How Does Students' Prior Knowledge Affect Their Learning?

But They Said They Knew This!

I recently taught Research Methods in Decision Sciences for the first time. On the first day of class, I asked my students what kinds of statistical tests they had learned in the introductory statistics course that is a prerequisite for my course. They generated a fairly standard list that included T-tests, chi-square, and ANOVA. Given what they told me, I was pretty confident that my first assignment was pitched at the appropriate level; it simply required that students take a data set that I provided, select and apply the appropriate statistical test from those they had already learned, analyze the data, and interpret the results. It seemed pretty basic, but I was shocked at what they handed in. Some students chose a completely inappropriate test while others chose the right test but did not have the foggiest idea how to apply it. Still others could not interpret the results. What I can't figure out is why they told me they knew this stuff when it's clear from their work that most of them don't have a clue.

Professor Soo Yon Won

Why Is This So Hard for Them to Understand?

Every year in my introductory psychology class I teach my students about classic learning theory, particularly the concepts of positive and negative reinforcement. I know that these can be tough concepts for students to grasp, so I spell out very clearly that *reinforcement* always refers to increasing a behavior and *punishment* always refers to decreasing a behavior. I also emphasize that, contrary to what they might assume, *negative reinforcement* does not mean punishment; it means removing something aversive to increase a desired behavior. I also provide a number of concrete examples to illustrate what I mean. But it seems that no matter how much I explain the concept, students continue to think of negative reinforcement as punishment. In fact, when I asked about negative reinforcement on a recent exam, almost 60 percent of the class got it wrong. Why is this so hard for students to understand?

Professor Anatole Dione

WHAT IS GOING ON IN THESE STORIES?

The instructors in these stories seem to be doing all the right things. Professor Won takes the time to gauge students' knowledge of statistical tests so that she can pitch her own instruction at the appropriate level. Professor Dione carefully explains a difficult concept, provides concrete examples, and even gives an explicit warning about a common misconception. Yet neither instructor's strategy is having the desired effect on students' learning and performance. To understand why, it is helpful to consider the effect of students' prior knowledge on new learning.

Professor Won assumes that students have learned and retained basic statistical skills in their prerequisite course, an

assumption that is confirmed by the students' self-report. In actuality, although students have some knowledge—they are able to identify and describe a variety of statistical tests—it may not be sufficient for Professor Won's assignment, which requires them to determine when particular tests are appropriate, apply the right test for the problem, and then interpret the results. Here Professor Won's predicament stems from a mismatch between the knowledge students have and the knowledge their instructor expects and needs them to have to function effectively in her course.

In Professor Dione's case it is not what students do *not* know that hurts them but rather what they *do* know. His students, like many of us, have come to associate positive with “good” and negative with “bad,” an association that is appropriate in many contexts, but not in this one. When students are introduced to the concept of negative reinforcement in relation to classic learning theory, their prior understanding of “negative” may interfere with their ability to absorb the technical definition. Instead of grasping that the “negative” in negative reinforcement involves removing something to get a positive change (an example would be a mother who promises to quit nagging if her son will clean his room), students interpret the word “negative” to imply a negative response, or punishment. In other words, their prior knowledge triggers an inappropriate association that ultimately intrudes on and distorts the incoming knowledge.

WHAT PRINCIPLE OF LEARNING IS AT WORK HERE?

As we teach, we often try to enhance our students' understanding of the course content by connecting it to their knowledge and experiences from earlier in the same course, from previous courses, or from everyday life. But sometimes—like Professor Won—we

overestimate students' prior knowledge and thus build new knowledge on a shaky foundation. Or we find—like Professor Dione—that our students are bringing prior knowledge to bear that is not appropriate to the context and which is distorting their comprehension. Similarly, we may uncover misconceptions and inaccuracies in students' prior knowledge that are actively interfering with their ability to learn the new material.

Although, as instructors, we can and should build on students' prior knowledge, it is also important to recognize that not all prior knowledge provides an equally solid foundation for new learning.

Principle: *Students' prior knowledge can help or hinder learning.*

Students do not come into our courses as blank slates, but rather with knowledge gained in other courses and through daily life. This knowledge consists of an amalgam of facts, concepts, models, perceptions, beliefs, values, and attitudes, some of which are accurate, complete, and appropriate for the context, some of which are inaccurate, insufficient for the learning requirements of the course, or simply inappropriate for the context. As students bring this knowledge to bear in our classrooms, it influences how they filter and interpret incoming information.

Ideally, students build on a foundation of robust and accurate prior knowledge, forging links between previously acquired and new knowledge that help them construct increasingly complex and robust knowledge structures (see Chapter Two). However, students may not make connections to relevant prior knowledge spontaneously. If they do not draw on relevant prior knowledge—in other words, if that knowledge is *inactive*—it may not facilitate the integration of new knowledge. Moreover, if students' prior

knowledge is *insufficient* for a task or learning situation, it may fail to support new knowledge, whereas if it is *inappropriate* for the context or *inaccurate*, it may actively distort or impede new learning. This is illustrated in Figure 1.1.

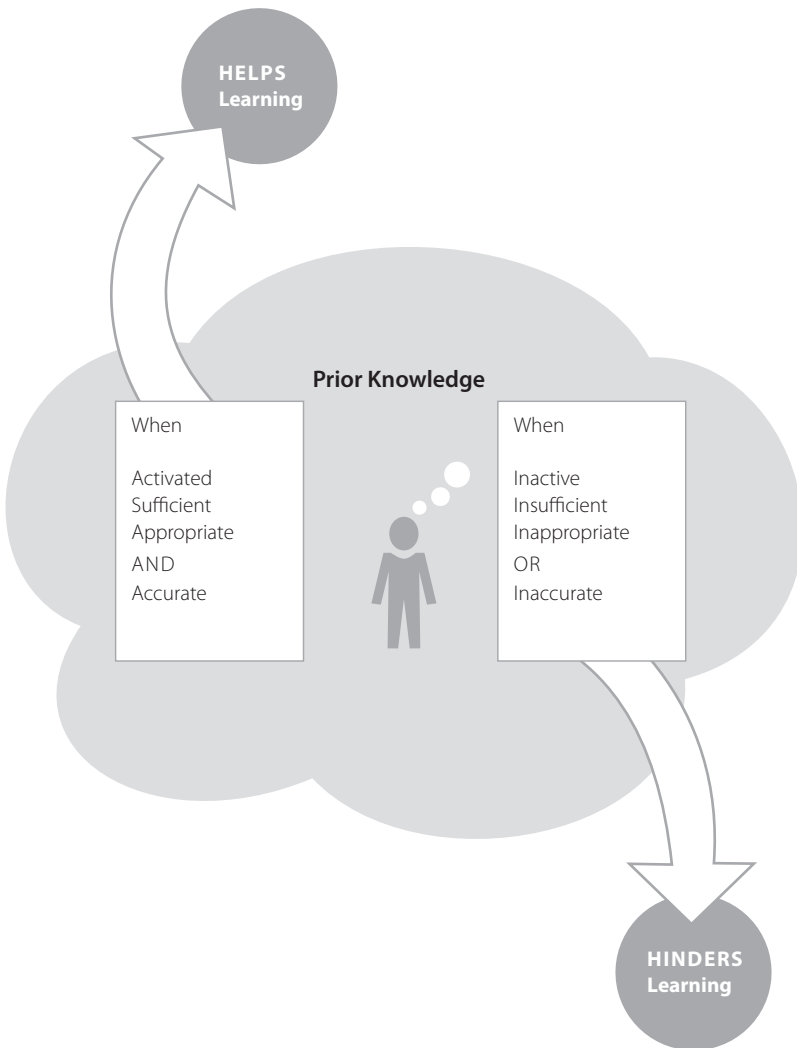


Figure 1.1. Qualities of Prior Knowledge That Help or Hinder Learning

Understanding what students know—or think they know—coming into our courses can help us design our instruction more appropriately. It allows us not only to leverage their accurate knowledge more effectively to promote learning, but also to identify and fill gaps, recognize when students are applying what they know inappropriately, and actively work to correct misconceptions.

WHAT DOES THE RESEARCH TELL US ABOUT PRIOR KNOWLEDGE?

Students connect what they learn to what they already know, interpreting incoming information, and even sensory perception, through the lens of their existing knowledge, beliefs, and assumptions (Vygotsky, 1978; National Research Council, 2000). In fact, there is widespread agreement among researchers that students *must* connect new knowledge to previous knowledge in order to learn (Bransford & Johnson, 1972; Resnick, 1983). However, the extent to which students are able to draw on prior knowledge to *effectively* construct new knowledge depends on the nature of their prior knowledge, as well as the instructor's ability to harness it. In the following sections, we discuss research that investigates the effects of various kinds of prior knowledge on student learning and explore its implications for teaching.

Activating Prior Knowledge

When students can connect what they are learning to accurate and relevant prior knowledge, they learn and retain more. In essence, new knowledge “sticks” better when it has prior knowledge to stick to. In one study focused on recall, for example, participants with variable knowledge of soccer were presented with scores from

different soccer matches and their recall was tested. People with more prior knowledge of soccer recalled more scores (Morris et al., 1981). Similarly, research conducted by Kole and Healy (2007) showed that college students who were presented with unfamiliar facts about well-known individuals demonstrated twice the capacity to learn and retain those facts as students who were presented with the same number of facts about unfamiliar individuals. Both these studies illustrate how prior knowledge of a topic can help students integrate new information.

However, students may not spontaneously bring their prior knowledge to bear on new learning situations (see the discussion of transfer in Chapter Four). Thus, it is important to help students activate prior knowledge so they can build on it productively. Indeed, research suggests that even small instructional interventions can activate students' relevant prior knowledge to positive effect. For instance, in one famous study by Gick and Holyoak (1980), college students were presented with two problems that required them to apply the concept of convergence. The researchers found that even when the students knew the solution to the first problem, the vast majority did not think to apply an analogous solution to the second problem. However, when the instructor suggested to students that they think about the second problem in relation to the first, 80 percent of the student participants were able to solve it. In other words, with minor prompts and simple reminders, instructors can activate relevant prior knowledge so that students draw on it more effectively (Bransford & Johnson, 1972; Dooling & Lachman, 1971).

Research also suggests that asking students questions specifically designed to trigger recall can help them use prior knowledge to aid the integration and retention of new information (Woloshyn, Paivio, & Pressley, 1994). For example, Martin and Pressley (1991) asked Canadian adults to read about events that had occurred in various Canadian provinces. Prior to any

instructional intervention, the researchers found that study participants often failed to use their relevant prior knowledge to logically situate events in the provinces where they occurred, and thus had difficulty remembering specific facts. However, when the researchers asked a set of “why” questions (for example, “Why would Ontario have been the first place baseball was played?”), participants were forced to draw on their prior knowledge of Canadian history and relate it logically to the new information. The researchers found that this intervention, which they called *elaborative interrogation*, improved learning and retention significantly.

Researchers have also found that if students are asked to generate relevant knowledge from previous courses or their own lives, it can help to facilitate their integration of new material (Peeck, Van Den Bosch, & Kruepeling, 1982). For example, Garfield and her colleagues (Garfield, Del Mas, & Chance, 2007) designed an instructional study in a college statistics course that focused on the concept of variability—a notoriously difficult concept to grasp. The instructors first collected baseline data on students’ understanding of variability at the end of a traditionally taught course. The following semester, they redesigned the course so that students were asked to generate examples of activities in their own lives that had either high or low variability, to represent them graphically, and draw on them as they reasoned about various aspects of variability. While both groups of students continued to struggle with the concept, post-tests showed that students who had generated relevant prior knowledge outperformed students in the baseline class two to one.

Exercises to generate prior knowledge can be a double-edged sword, however, if the knowledge students generate is inaccurate or inappropriate for the context (Alvermann, Smith, & Readance, 1985). Problems involving inaccurate and inappropriate prior knowledge will be addressed in the next two sections.

Implications of This Research Students learn more readily when they can connect what they are learning to what they already know. However, instructors should not assume that students will immediately or naturally draw on relevant prior knowledge. Instead, they should deliberately activate students' prior knowledge to help them forge robust links to new knowledge.

Accurate but Insufficient Prior Knowledge

Even when students' prior knowledge is accurate and activated, it may not be sufficient to support subsequent learning or a desired level of performance. Indeed, when students possess *some* relevant knowledge, it can lead both students and instructors to assume that students are better prepared than they truly are for a particular task or level of instruction.

In fact, there are many different types of knowledge, as evidenced by a number of typologies of knowledge (for example, Anderson & Krathwohl, 2001; Anderson, 1983; Alexander, Schallert, & Hare, 1991; DeJong & Ferguson-Hessler, 1996). One kind of knowledge that appears across many of these typologies is *declarative knowledge*, or the knowledge of facts and concepts that can be stated or declared. Declarative knowledge can be thought of as “knowing what.” The ability to name the parts of the circulatory system, describe the characteristics of hunter-gatherer social structure, or explain Newton's Third Law are examples of declarative knowledge. A second type of knowledge is often referred to as *procedural knowledge*, because it involves knowing how and knowing when to apply various procedures, methods, theories, styles, or approaches. The ability to calculate integrals, draw with 3-D perspective, and calibrate lab equipment—as well as the knowledge of when these skills are and are not applicable—fall into the category of procedural knowledge.

Declarative and procedural knowledge are not the same, nor do they enable the same kinds of performance. It is common, for instance, for students to know facts and concepts but not know how or when to apply them. In fact, research on science learning demonstrates that even when students can state scientific facts (for example, “Force equals mass times acceleration”), they are often weak at applying those facts to solve problems, interpret data, and draw conclusions (Clement, 1982). We see this problem clearly in Professor Won’s class. Her students know *what* various statistical tests are, but this knowledge is insufficient for the task Professor Won has assigned, which requires them to select appropriate tests for a given data set, execute the statistical tests properly, and interpret the results.

Similarly, studies have shown that students can often perform procedural tasks without being able to articulate a clear understanding of what they are doing or why (Berry & Broadbent, 1988; Reber & Kotovsky, 1997; Sun, Merrill, & Peterson, 2001). For example, business students may be able to apply formulas to solve finance problems but not to explain their logic or the principles underlying their solutions. Similarly, design students may know how to execute a particular design without being able to explain or justify the choices they have made. These students may have sufficient procedural knowledge to function effectively in specific contexts, yet lack the declarative knowledge of deep features and principles that would allow them both to adapt to different contexts (see discussion of transfer in Chapter Three) and explain themselves to others.

Implications of This Research Because *knowing what* is a very different kind of knowledge than *knowing how* or *knowing when*, it is especially important that, as instructors, we are clear in our own minds about the knowledge requirements of different tasks and

that we not assume that because our students have one kind of knowledge that they have another. Instead, it is critical to assess both the amount and nature of students' prior knowledge so that we can design our instruction appropriately.

Inappropriate Prior Knowledge

Under some circumstances, students draw on prior knowledge that is inappropriate for the learning context. Although this knowledge is not necessarily inaccurate, it can skew their comprehension of new material.

One situation in which prior knowledge can distort learning and performance is when students import everyday meanings into technical contexts. Several studies in statistics, for example, show how commonplace definitions of terms such as *random* and *spread* intrude in technical contexts, distorting students' understandings of statistical concepts (Del Mas & Liu, 2007; Kaplan, Fisher, & Rogness, 2009). This seems to be the problem for Professor Dione's students, whose everyday associations with the terms *positive* and *negative* may have skewed their understanding of *negative reinforcement*.

Another situation in which inappropriate prior knowledge can impede new learning is if students analogize from one situation to another without recognizing the limitations of the analogy. For the most part, analogies serve an important pedagogical function, allowing instructors to build on what students already know to help them understand complex, abstract, or unfamiliar concepts. However, problems can arise when students do not recognize where the analogy breaks down or fail to see the limitations of a simple analogy for describing a complex phenomenon. For example, skeletal muscles and cardiac muscles share some traits; hence, drawing analogies between them makes sense to a point. However, the differences in how these two types of muscles func-

tion are substantial and vital to understanding their normal operation, as well as for determining how to effectively intervene in a health crisis. In fact, Spiro and colleagues (Spiro et al., 1989) found that many medical students possess a misconception about a potential cause of heart failure that can be traced to their failure to recognize the limitations of the skeletal muscle-cardiac muscle analogy.

Knowledge from one disciplinary context, moreover, may obstruct learning and performance in another disciplinary context if students apply it inappropriately. According to Beaufort (2007), college composition courses sometimes contribute to this phenomenon by teaching a generic approach to writing that leaves students ill-prepared to write well in particular domains. Because students come to think of writing as a “one size fits all” skill, they misapply conventions and styles from their general writing classes to disciplinary contexts in which they are not appropriate. For example, they might apply the conventions of a personal narrative or an opinion piece to writing an analytical paper or a lab report. Beaufort argues that without remediation, this intrusion of inappropriate knowledge can affect not only students’ performance but also their ability to internalize the rhetorical conventions and strategies of the new discipline.

Furthermore, learning can also be impeded when linguistic knowledge is applied to contexts where it is inappropriate (Bartlett, 1932). For example, when many of us are learning a foreign language, we apply the grammatical structure we know from our native language to the new language. This can impede learning when the new language operates according to fundamentally different grammatical rules, such as a subject-object-verb configuration as opposed to a subject-verb-object structure (Thonis, 1981).

Similarly, misapplication of cultural knowledge can—and often does—lead to erroneous assumptions. For example, when

Westerners draw on their own cultural knowledge to interpret practices such as veiling in the Muslim world, they may misinterpret the meaning of the veil to the women who wear it. For instance, Westerners may assume that veiling is a practice imposed by men on unwilling women or that Muslim women who veil do so to hide their beauty. In fact, neither of these conclusions is necessarily accurate; for instance, some Muslim women voluntarily choose to cover—sometimes against the wishes of male family members—as a statement of modern religious and political identity (Ahmed, 1993; El Guindi, 1999). By the same token, some women think of the veil as a way to accentuate, not conceal, beauty (Wikan, 1982). Yet if Westerners interpret these practices through the lens of their own prior cultural knowledge and assumptions, they may emerge with a distorted understanding that can impede further learning.

Research suggests that if students are explicitly taught the conditions and contexts in which knowledge is applicable (and inapplicable), it can help them avoid applying prior knowledge inappropriately. Moreover, if students learn abstract principles to guide the application of their knowledge and are presented with multiple examples and contexts in which to practice applying those principles, it not only helps them recognize when their prior knowledge is relevant to a particular context (see Chapter Four on transfer), but also helps them avoid misapplying knowledge in the wrong contexts (Schwartz et al., 1999). Researchers also observe that making students explicitly aware of the limitations of a given analogy can help them learn not to approach analogies uncritically or stretch a simple analogy too far (Spiro et al., 1989).

Another way to help students avoid making inappropriate associations or applying prior knowledge in the wrong contexts is to deliberately activate their relevant prior knowledge (Minstrell, 1989, 1992). If we recall Professor Dione's course from the story at the beginning of the chapter, we can imagine a potential appli-

cation for this idea. When presented with the counterintuitive concept of negative reinforcement, Professor Dione's students drew on associations (of positive as desirable and negative as undesirable) that were interfering with their comprehension. However, if Professor Dione had tried activating a different set of associations—namely of positive as adding and negative as subtracting—he may have been able to leverage those associations to help his students understand that positive reinforcement involves adding something to a situation to increase a desired behavior whereas negative reinforcement involves subtracting something to increase a desired behavior.

Implications of This Research When learning new material, students may draw on knowledge (from everyday contexts, from incomplete analogies, from other disciplinary contexts, and from their own cultural or linguistic backgrounds) that is inappropriate for the context, and which can distort their interpretation of new material or impede new learning. To help students learn where their prior knowledge is and is not applicable, it is important for instructors to (a) clearly explain the conditions and contexts of applicability, (b) teach abstract principles but also provide multiple examples and contexts, (c) point out differences, as well as similarities, when employing analogies, and (d) deliberately activate relevant prior knowledge to strengthen appropriate associations.

Inaccurate Prior Knowledge

We have seen in the sections above that prior knowledge will not support new learning if it is insufficient or inappropriate for the task at hand. But what if it is downright wrong? Research indicates that inaccurate prior knowledge (in other words, flawed ideas, beliefs, models, or theories) can distort new knowledge by

predisposing students to ignore, discount, or resist evidence that conflicts with what they believe to be true (Dunbar, Fugelsang, & Stein, 2007; Chinn & Malhotra, 2002; Brewer & Lambert, 2000; Fiske & Taylor, 1991; Alvermann, Smith, & Readance, 1985). Some psychologists explain this distortion as a result of our striving for internal consistency. For example, Vosniadou and Brewer (1987) found that children reconcile their perception that the earth is flat with formal instruction stating that the earth is round by conceiving of the earth as a pancake: circular but with a flat surface. In other words, children—like all learners—try to make sense of what they are learning by fitting it into what they already know or believe.

Inaccurate prior knowledge can be corrected fairly easily if it consists of relatively isolated ideas or beliefs that are not embedded in larger conceptual models (for example, the belief that Pluto is a planet or that the heart oxygenates blood). Research indicates that these sorts of beliefs respond to refutation; in other words, students will generally revise them when they are explicitly confronted with contradictory explanations and evidence (Broughton, Sinatra, & Reynolds, 2007; Guzetti, Snyder, Glass, & Gamas, 1993; Chi, 2008). Even more integrated—yet nonetheless flawed—conceptual models may respond to refutation over time if the individual inaccuracies they contain are refuted systematically (Chi & Roscoe, 2002).

However, some kinds of inaccurate prior knowledge—called *misconceptions*—are remarkably resistant to correction. Misconceptions are models or theories that are deeply embedded in students' thinking. Many examples have been documented in the literature, including naïve theories in physics (such as the notion that objects of different masses fall at different rates), “folk psychology” myths (for example, that blind people have more sensitive hearing than sighted people or that a good hypnotist can command total obedience), and stereotypes about groups

of people (Brown, 1983; Kaiser, McCloskey, & Proffitt, 1986; McCloskey, 1983; Taylor & Kowalski, 2004).

Misconceptions are difficult to refute for a number of reasons. First, many of them have been reinforced over time and across multiple contexts. Moreover, because they often include accurate—as well as inaccurate—elements, students may not recognize their flaws. Finally, in many cases, misconceptions may allow for successful explanations and predictions in a number of everyday circumstances. For example, although stereotypes are dangerous oversimplifications, they are difficult to change in part because they fit aspects of our perceived reality and serve an adaptive human need to generalize and categorize (Allport, 1954; Brewer, 1988; Fiske & Taylor, 1991).

Research has shown that deeply held misconceptions often persist despite direct instructional interventions (Ram, Nersessian, & Keil, 1997; Gardner & Dalsing, 1986; Gutman, 1979; Confrey, 1990). For example, Stein and Dunbar conducted a study (described in Dunbar, Fugelsang, & Stein, 2007) in which they asked college students to write about why the seasons changed, and then assessed their relevant knowledge via a multiple choice test. After finding that 94 percent of the students in their study had misconceptions (including the belief that the shape of the earth's orbit was responsible for the seasons), the researchers showed students a video that clearly explained that the tilt of the earth's axis, not the shape of the earth's orbit, was responsible for seasonal change. Yet in spite of the video, when students were asked to revise their essays, their explanations for the seasons did not change fundamentally. Similarly, McCloskey, Caramazza, and Green (1980) found that other deeply held misconceptions about the physical world persist even when they are refuted through formal instruction.

Results like these are sobering. Yet the picture is not altogether gloomy. To begin with, it is important to recognize that

conceptual change often occurs gradually and may not be immediately visible. Thus, students may be moving in the direction of more accurate knowledge even when it is not yet apparent in their performance (Alibali, 1999; Chi & Roscoe, 2002). Moreover, even when students retain inaccurate beliefs, they can learn to inhibit and override those beliefs and draw on accurate knowledge instead. Research indicates, for instance, that when people are sufficiently motivated to do so, they can consciously suppress stereotypical judgments and learn to rely on rational analysis more and stereotypes less (Monteith & Mark, 2005; Monteith, Sherman, & Devine, 1998). Moreover, since consciously overcoming misconceptions requires more cognitive energy than simply falling back on intuitive, familiar modes of thinking, there is research to suggest that when distractions and time pressures are minimized, students will be more likely to think rationally and avoid applying misconceptions and flawed assumptions (Finucane et al., 2000; Kahnemann & Frederick, 2002).

In addition, carefully designed instruction can help wean students from misconceptions through a process called *bridging* (Brown, 1992; Brown & Clement, 1989; Clement, 1993). For example, Clement observed that students often had trouble believing that a table exerts force on a book placed on its surface. To help students grasp this somewhat counterintuitive concept, he designed an instructional intervention for high school physics students that started from students' accurate prior knowledge. Because students did believe that a compressed spring exerted force, the researchers were able to analogize from the spring to foam, then to pliable wood, and finally to a solid table. The intermediate objects served to bridge the difference between a spring and the table and enabled the students to extend their accurate prior knowledge to new contexts. Using this approach, Clement obtained significantly greater pre- to posttest gains compared to traditional classroom instruction. In a similar vein, Minstrell's

research (1989) shows that students can be guided away from misconceptions through a process of reasoning that helps them build on the accurate facets of their knowledge as they gradually revise the inaccurate facets.

Implications of This Research It is important for instructors to address inaccurate prior knowledge that might otherwise distort or impede learning. In some cases, inaccuracies can be corrected simply by exposing students to accurate information and evidence that conflicts with flawed beliefs and models. However, it is important for instructors to recognize that a single correction or refutation is unlikely to be enough to help students revise deeply held misconceptions. Instead, guiding students through a process of conceptual change is likely to take time, patience, and creativity.

WHAT STRATEGIES DOES THE RESEARCH SUGGEST?

In this section we offer (1) a set of strategies to help instructors determine the extent and quality of students' prior knowledge, relative to the learning requirements of a course. We then provide strategies instructors can employ to (2) activate students' relevant prior knowledge, (3) address gaps in students' prior knowledge, (4) help students avoid applying prior knowledge in the wrong contexts, and (5) help students revise and rethink inaccurate knowledge.

Methods to Gauge the Extent and Nature of Students' Prior Knowledge

Talk to Colleagues As a starting point for finding out what prior knowledge students bring to your course, talk to colleagues

who teach prerequisite courses or ask to see their syllabi and assignments. This can give you a quick sense of what material was covered, and in what depth. It can also alert you to differences in approach, emphasis, terminology, and notation so that you can address potential gaps or discrepancies. Remember, though, that just because the material was taught does not mean that students necessarily learned it. To get a better sense of students' knowledge, as well as their ability to apply it, you might also ask your colleagues about students' proficiencies: for example, what concepts and skills did students seem to master easily? Which ones did they struggle with? Did students seem to hold any systematic and pervasive misconceptions? This kind of information from colleagues can help you design your instructional activities so they effectively connect to, support, extend, and, if needed, correct, students' prior knowledge.

Administer a Diagnostic Assessment To find out what relevant knowledge students possess coming into your course, consider assigning a short, low-stakes assessment, such as a quiz or an essay, at the beginning of the semester. Students' performance on this assignment can give you a sense of their knowledge of prerequisite facts and concepts, or their competence in various skills. For example, if your course requires knowledge of a technical vocabulary and basic calculus skills, you could create a short quiz asking students to define terms and solve calculus problems. You can mark these assignments individually to get a sense of the skill and knowledge of particular students, or simply look them over as a set to get a feel for students' overall level of preparedness. Another way to expose students' prior knowledge is by administering a concept inventory. Concept inventories are ungraded tests, typically in a multiple-choice format, that are designed to include incorrect answers that help reveal common misconceptions. Developing a concept inventory of your own can be time-

intensive, so check the Internet to see whether there are inventories already available in your discipline that would suit your needs. A number of concept inventories have been widely used and have high validity and reliability.

Have Students Assess Their Own Prior Knowledge In some fields and at some levels of expertise, having students assess their own knowledge and skills can be a quick and effective—though not necessarily foolproof—way to diagnose missing or insufficient prior knowledge. One way to have students self-assess is to create a list of concepts and skills that you expect them to have coming into your course, as well as some concepts and skills you expect them to acquire during the semester. Ask students to assess their level of competence for each concept or skill, using a scale that ranges from cursory familiarity (“I have heard of the term”) to factual knowledge (“I could define it”) to conceptual knowledge (“I could explain it to someone else”) to application (“I can use it to solve problems”). Examine the data for the class as a whole in order to identify areas in which your students have either less knowledge than you expect or more. In either case, this information can help you recalibrate your instruction to better meet student needs. See Appendix A for more information about student self-assessments.

Use Brainstorming to Reveal Prior Knowledge One way to expose students' prior knowledge is to conduct a group brainstorming session. Brainstorming can be used to uncover beliefs, associations, and assumptions (for example, with questions such as “What do you think of when you hear the word *evangelical*?”). It can also be used to expose factual or conceptual knowledge (“What were some of the key historical events in the Gilded Age?” or “What comes to mind when you think about environmental ethics?”), procedural knowledge (“If you were going to do a

research project on the Farm Bill, where would you begin?”), or contextual knowledge (“What are some methodologies you could use to research this question?”). Bear in mind that brainstorming does not provide a systematic gauge of students’ prior knowledge. Also, be prepared to differentiate accurate and appropriately applied knowledge from knowledge that is inaccurate or inappropriately applied.

Assign a Concept Map Activity To gain insights into what your students know about a given subject, ask them to construct a concept map representing everything that they know about the topic. You can ask students to create a concept map (see Appendix B), representing what they know about an entire disciplinary domain (for example, social psychology), a particular concept (for instance, Newton’s third law), or a question (for example, “What are the ethical issues with stem cell research?”). Some students may be familiar with concept maps, but others may not be, so be sure to explain what they are and how to create them (circles for concepts, lines between concepts to show how they relate). There are a number of ways to construct concept maps, so you should give some thought to what you are trying to ascertain. For instance, if you are interested in gauging students’ knowledge of concepts as well as their ability to articulate the connections among them, you can ask students to generate both concepts and links. But if you are primarily interested in students’ ability to articulate the connections, you can provide the list of concepts and ask students to arrange and connect them, labeling the links. If there are particular kinds of information you are looking for (for example, causal relationships, examples, theoretical orientations) be sure to specify what you want. Review the concept maps your students create to try to determine gaps in their knowledge, inappropriate links, and the intrusion of lay terms and ideas that may indicate the presence of naïve theories or preconceptions.

Look for Patterns of Error in Student Work Students' misconceptions tend to be shared and produce a consistent pattern of errors. You (or your TAs or graders) can often identify these misconceptions simply by looking at students' errors on homework assignments, quizzes, or exams and noting commonalities across the class. You can also keep track of the kinds of problems and errors that students reveal when they come to office hours or as they raise or answer questions during class. Paying attention to these patterns of error can alert you to common problems and help you target instruction to correct misconceptions or fill gaps in understanding. Some instructors use classroom response systems (also called "clickers") to quickly collect students' answers to concept questions posed in class. Clickers provide an instant histogram of students' answers and can alert instructors to areas of misunderstanding that might stem from insufficient prior knowledge.

Methods to Activate Accurate Prior Knowledge

Use Exercises to Generate Students' Prior Knowledge

Because students learn most effectively when they connect new knowledge to prior knowledge, it can be helpful to begin a lesson by asking students what they already know about the topic in question. This can be done any number of ways, such as by asking students to brainstorm associations or create a concept map. Once students have activated relevant prior knowledge in their heads, they are likely to be able to integrate new knowledge more successfully. However, since activities like this can generate inaccurate and inappropriate as well as accurate and relevant knowledge, you should be prepared to help students distinguish between them.

Explicitly Link New Material to Knowledge from Previous Courses Students tend to compartmentalize knowledge by

course, semester, professor, or discipline. As a result, they may not recognize the relevance of knowledge from a previous course to a new learning situation. For example, students who have learned about the concept of variability in a statistics course often do not bring that knowledge to bear on the concept of volatility in a finance course both because of the difference in terminology and because they do not see the link between the two contexts. However, if you make the connection between variability and volatility explicit, it allows students to tap into that prior knowledge and build on it productively.

Explicitly Link New Material to Prior Knowledge from Your Own Course Although we often expect students to automatically link what they are learning to knowledge gained earlier in the same course, they may not do so automatically. Thus, it is important for instructors to highlight these connections. Instructors can help students activate relevant prior knowledge by framing particular lectures, discussions, or readings in relation to material learned previously in the semester. For example, in a literary theory course, the professor might begin class by saying, “In Unit 2 we discussed feminist theory. Today we are going to talk about a school of thought that grew out of feminist theory.”) Sometimes all it takes to activate students’ relevant prior knowledge is a slight prompt, such as: “Think back to the research design Johnson used in the article from last week” or “Where have we seen this phenomenon before?” Students can also be encouraged to look for connections within course materials in other ways. For example, the instructor can ask students to write reflection papers that connect each reading to other readings and to larger themes in the course. Also, discussions provide an ideal opportunity to elicit students’ knowledge from earlier in the semester and to link it to new material.

Use Analogies and Examples That Connect to Students' Everyday Knowledge Examples or analogies that draw on students' everyday lives and the wider world make new material more understandable and create more robust knowledge representations in students' minds. For example, an instructor could draw on students' memories from childhood and experiences with younger siblings to help them understand concepts in child development. Similarly, an instructor could use students' experiences with the physical world to introduce concepts such as force and acceleration. Analogies are also useful for connecting new knowledge to prior knowledge. For example, students' experience with cooking can be enlisted to help them understand scientific processes such as chemical synthesis (just as in cooking, when you mix or heat chemicals, you need to know when precision is and is not critical). Students often show more sophisticated reasoning when working in familiar contexts, and we can build on their knowledge from these contexts as we explore new material.

Ask Students to Reason on the Basis of Relevant Prior Knowledge Often students have prior knowledge that could help them reason about new material and learn it more deeply. Thus, it can be useful to ask students questions that require them to use their prior knowledge to make predictions about new information before they actually encounter it. For example, before asking students to read an article from the 1970s, you might ask them what was going on historically at the time that might have informed the author's perspective. Or when presenting students with a design problem, you might ask them how a famous designer, whose work they know, might have approached the problem. This requires students not only to draw on their prior knowledge but also to use it to reason about new knowledge.

Methods to Address Insufficient Prior Knowledge

Identify the Prior Knowledge You Expect Students to Have The first step toward addressing gaps in students' prior knowledge is recognizing where those gaps are. This requires identifying in your own mind the knowledge students will need to have to perform effectively in your course. To identify what the prior knowledge requirements are for your class, you might want to begin by thinking about your assignments, and ask yourself, "What do students need to know to be able to do this?" Often instructors stop short of identifying all the background knowledge students need, so be sure to continue asking the question until you have fully identified the knowledge requirements for the tasks you have assigned. Be sure to differentiate declarative (knowing what and knowing why) from procedural knowledge (knowing how and knowing when), recognizing that just because students know facts or concepts does not mean they will know how to use them, and just because students know how to perform procedures does not mean that they understand what they are doing or why. (See "Strategies to Expose and Reinforce Component Skills" in Chapter Four.)

Remediate Insufficient Prerequisite Knowledge If prior knowledge assessments (as discussed in previous strategies) indicate critical gaps in students' prior knowledge relative to the learning requirements of your course, there are a number of possible responses depending on the scale of the problem and the resources and options available to you and to your students. If only a few students lack important prerequisite knowledge, one option that might be open to you is simply to advise them against taking the course until they have the necessary background. Alternatively, if a small number of students lacks prerequisite knowledge but seem capable of acquiring it on their own, you might consider

providing these students with a list of terms they should know and skills they should have and letting them fill in the gaps on their own time. If a larger number of students lacks sufficient prior knowledge in a key area, you might decide to devote one or two classes to a review of important prerequisite material or (if it is applicable) ask your teaching assistant to run a review session outside class time. If a sizable proportion of your class lacks knowledge that is a critical foundation for the material you planned to cover, you may need to revise your course altogether so that it is properly aligned with your students' knowledge and skills. Of course, if your course is a prerequisite for other courses, such fundamental revisions may have broader implications, which may need to be addressed at a departmental level through a discussion of objectives and course sequencing.

Methods to Help Students Recognize Inappropriate Prior Knowledge

Highlight Conditions of Applicability It is important to help students see when it is and is not appropriate to apply prior knowledge. For example, a statistics instructor might explain that a regression analysis can be used for quantitative variables but not for qualitative variables, or a biology instructor might instruct students to save their expressive writing for other courses and instead write lab reports that focus on conciseness and accuracy. If there are no strict rules about when prior knowledge is applicable, another strategy is to present students with a range of problems and contexts and ask them to identify whether or not a given skill or concept is applicable and to explain their reasoning.

Provide Heuristics to Help Students Avoid Inappropriate Application of Knowledge One strategy to help students avoid applying their prior knowledge inappropriately is to provide them

with some rules of thumb to help them determine whether their knowledge is or is not relevant. For example, when students are encountering different cultural practices and might be tempted to assess them according to their own cultural norms, you might encourage them to ask themselves questions such as “Am I making assumptions based on my own cultural knowledge that may not be appropriate here? If so, what are those assumptions, and where do they come from?” By the same token, if you know of situations in which students frequently get confused by the intrusion of prior knowledge (for example, students’ understanding of negative reinforcement in the second story at the beginning of this chapter), you might want to provide them with a rule of thumb to help them avoid that pitfall. For example, an instructor teaching classical learning theory could advise his students, “When you see ‘negative’ in the context of negative reinforcement, think of subtraction.”

Explicitly Identify Discipline-Specific Conventions It is important to clearly identify the conventions and expectations of your discipline so that students do not mistakenly apply the conventions of other domains about which they know more. For example, students may have experience with writing from a science course (lab reports), from a history course (analytical paper), or from an English course (personal narrative), so when they take a public policy course they may not know which set of knowledge and skills is the appropriate one to build on. It is important to explicitly identify the norms you expect them to follow. Without explicit guidance, students may analogize from other experiences or fields that they feel most competent in, regardless of whether the experiences are appropriate in the current context.

Show Where Analogies Break Down Analogies can help students learn complex or abstract concepts. However, they can be

problematic if students do not recognize their limits. Thus, it is important to help students recognize the limitations of a given analogy by explicitly identifying (or asking students to identify) where the analogy breaks down. For example, you might point out that although the digestive system is similar to plumbing in that it involves tube-like organs and various kinds of valves, it is far more complex and sensitive than any ordinary plumbing system.

Methods to Correct Inaccurate Knowledge

Ask Students to Make and Test Predictions To help students revise inaccurate beliefs and flawed mental models ask them to make predictions based on those beliefs and give them the opportunity to test those predictions. For example, physics students with an inaccurate understanding of force could be asked to make predictions about how forces will act on stationary versus moving objects. Being confronted with evidence that contradicts students' beliefs and expectations can help them see where their knowledge or beliefs are incorrect or inadequate, while motivating them to seek knowledge that accounts for what they have seen. Predictions can be tested in experiments, in or outside a laboratory environment, or through the use of computer simulations.

Ask Students to Justify Their Reasoning One strategy to guide students away from inaccurate knowledge is to ask them to reason on the basis of what they believe to be true. When students' reasoning reveals internal contradictions, it can bring them to the point where they seek accurate knowledge. A caveat to this approach is that students may not necessarily see those internal contradictions. Moreover, if their attitudes and beliefs are very deeply held (for example, religious beliefs that defy logical argument), these contradictions may have little effect.

Provide Multiple Opportunities for Students to Use Accurate Knowledge Misconceptions can be hard to correct in part because they have been reinforced through repeated exposure. Thus, replacing inaccurate knowledge with accurate knowledge requires not just introducing accurate knowledge but also providing multiple opportunities for students to use it. Repeated opportunities to apply accurate knowledge can help counteract the persistence of even deeply held misconceptions.

Allow Sufficient Time It is easier for students to fall back on deeply held misconceptions than to employ the reasoning necessary to overcome them. Therefore, when you are asking students to use new knowledge that requires a revision or rethinking of their prior knowledge, it can be helpful to minimize distractions and allow a little extra time. This can help students enlist the cognitive resources necessary to identify flaws in their knowledge or reasoning and instead to consciously employ more thoughtful, critical thinking.

SUMMARY

In this chapter we have examined the critical role of prior knowledge in laying the groundwork for new learning. We have seen that if students' prior knowledge has gaps and insufficiencies it may not adequately support new knowledge. Moreover, if prior knowledge is applied in the wrong context, it may lead students to make faulty assumptions or draw inappropriate parallels. In addition, inaccurate prior knowledge—some of which can be surprisingly difficult to correct—can both distort students' understanding and interfere with incoming information. Consequently,

a critical task for us as instructors is to assess what students know and believe so we can build on knowledge that is accurate and relevant, fill in gaps and insufficiencies where they exist, help students recognize when they are applying prior knowledge inappropriately, and help students revise inaccurate knowledge and form more accurate and robust mental models.