CHAPTER 2

How Does the Way Students Organize Knowledge Affect Their Learning?

That Didn't Work Out the Way I Anticipated

For the past 12 years, I've taught the introductory Art History course. I present the material using a standard approach. That is, I begin with an introductory description of key terms and concepts, including a discussion of the basic visual elements (line, color, light, form, composition, space). Then, for each of the remaining 40 class sessions, I show slides of important works, progressing chronologically from prehistoric Europe to rather recent pieces. As I go, I identify important features that characterize each piece and point out associations among various movements, schools, and periods. I give a midterm and a final exam during which I present slides and ask students to identify the title of the work, the artist, the school, and the period in which it was produced. While the students seem to enjoy the class sessions, they complain about the amount of material they must memorize for the exams. I know there are a lot of individual pieces, but they naturally cluster by period, school, and technique. Once you categorize a work according to those groupings, it should be fairly easy to remember. Nevertheless, the students seem to

be having a lot of difficulty in my exams identifying even some of the most important pieces.

Professor Rachel Rothman

There Must Be a Better Way!

Anatomy and Physiology is one of the core courses required for our nursing, pre-med, and pharmacy students. The course is organized around the major systems of the body and requires students to identify and describe the location and function of the major organs, bones, muscles, and tissues in the body. On the whole, students attend the lectures and labs consistently, and most of them appear to work really hard. Indeed, I often find them in the student lounge poring over their notes or quizzing each other in order to memorize all the individual structures. With a lot of work, they learn to identify most of the parts of the human body and can describe the role of each part in its body system. However, when asked to explain the relationships among parts or higher-order principles that cut across systems, the students often fall apart. For example, on the last exam I asked them to identify and describe all the structures involved in the regulation of blood pressure. To my surprise, most of the students were unable to answer the question correctly. I just don't get it—they know all the parts, but when it comes to how those parts fit together, they have a really difficult time.

Professor Anand Patel

WHAT IS GOING ON IN THESE TWO STORIES?

Although the content of the courses in these two stories differs substantially, the two instructors have similar goals. They want their students to develop a deep, functional understanding of a

multifaceted, complex domain. In the first story, the domain is the accumulated corpus of artistic expression created by humans over the past 30,000 years. In the second story, the domain is the complex array of organs, systems, and interacting parts that make up the human body. Each domain comprises many individual elements, and each element—be it a bone in the wrist or Picasso's *Guernica*—is related to other elements in important ways. Knowing about these elements but also having a meaningful picture of how they are related to each other is critical to deep understanding. In each of the stories, however, the students appear to lack a sufficiently coherent, organized representation of the material, which impedes their learning and performance.

In the first story, Professor Rothman provides her students with the concepts and vocabulary to analyze the visual elements in works of art and to make connections across various artists, schools, and periods. Then, for the rest of the semester she presents works of art in chronological order, referring to the key features of each piece of art she presents. It appears, however, that mentioning these features in relation to individual works was not sufficient to enable her students to see deeper relationships and make broader connections among clusters of works. That is, while these relationships and comparisons are natural to Professor Rothman, providing her with an easy way to group and organize the factual information, her students may not have made the same connections. Instead, they may have latched onto chronology as the prominent organizing principle for the material and hence organized their knowledge along a time line. Because this chronological structure for organizing knowledge entails remembering a great number of isolated facts, without any other overarching organizational structure to facilitate information retrieval and use, these students may be struggling (and largely failing) to memorize what they need to know for the exam.

In the second story, Professor Patel's students have knowledge of the individual parts of the human body, but this knowledge does not translate into an understanding of how those parts are functionally related to one another. One reason for this may be that students have organized their knowledge much the same way as a standard Anatomy and Physiology textbook: according to the major body systems (for example, the skeletal system, the digestive system, the circulatory system). If Professor Patel's students have organized their knowledge around discrete parts of the body, it could have several effects on their ability to use this information. If these students were asked to name the major bones of the hand or the function of the pancreas, they would probably have little difficulty, since such questions mesh well with how they have organized the information. However, to answer Professor Patel's question about how various structures work together to regulate blood pressure, these students would need an alternative way to organize their knowledge—one including the functional relationships that cut across multiple systems, not simply parts in isolation. In other words, the way these students have organized their knowledge facilitates one kind of use, but it is not sufficiently flexible to support the demands of all the tasks they face.

WHAT PRINCIPLE OF LEARNING IS AT WORK HERE?

As experts in our fields, we create and maintain, often unconsciously, a complex network that connects the important facts, concepts, procedures, and other elements within our domain. Moreover, we organize our domain knowledge around meaningful features and abstract principles. In contrast, most of our students have not yet developed such connected or meaningful ways

of organizing the information they encounter in our courses. Yet how they organize their knowledge has profound implications for their learning, a point that is highlighted in our next principle.

Principle: *How students organize knowledge influences how they learn and apply what they know.*

When we talk about the way people organization their knowledge (or, for the sake of simplicity, their *knowledge organizations*), we are not talking about particular pieces of knowledge, but rather how those pieces are arranged and connected in an individual's mind. Knowledge can be organized in ways that either do or do not facilitate learning, performance, and retention.

As an illustration, consider two students who are asked to identify the date when the British defeated the Spanish Armada (National Research Council, 2001). The first student tells us that the battle happened in 1588, and the second says that he cannot remember the precise date but thinks it must be around 1590. Given that 1588 is the correct answer for this historical date, the first student appears to have more accurate knowledge. Suppose, however, that we probe the students further and ask how they arrived at their answers. The first student then says that he memorized the correct date from a book. In contrast, the second students says that he based his answer on his knowledge that the British colonized Virginia just after 1600 and on the inference that the British would not dare organize massive overseas voyages for colonization until navigation was considered safe. Figuring that it took about 10 years for maritime traffic to be properly organized, he arrived at his answer of 1590.

These students' follow-up answers reveal knowledge organizations of different quality. The first student has learned an isolated fact about the Spanish Armada, apparently unconnected in

his mind to any related historical knowledge. In contrast, the second student seems to have organized his knowledge in a much more interconnected (and causal) way that enabled him to reason about the situation in order to answer the question. The first student's sparse knowledge organization would likely not offer much support for future learning, whereas the second student's knowledge organization would provide a more robust foundation for subsequent learning.

Although the two students in this example are both relative novices, the differences in their knowledge organizations correspond, in very rough terms, to the differences between novices and experts. As illustrated in Figure 2.1, novice and expert knowledge

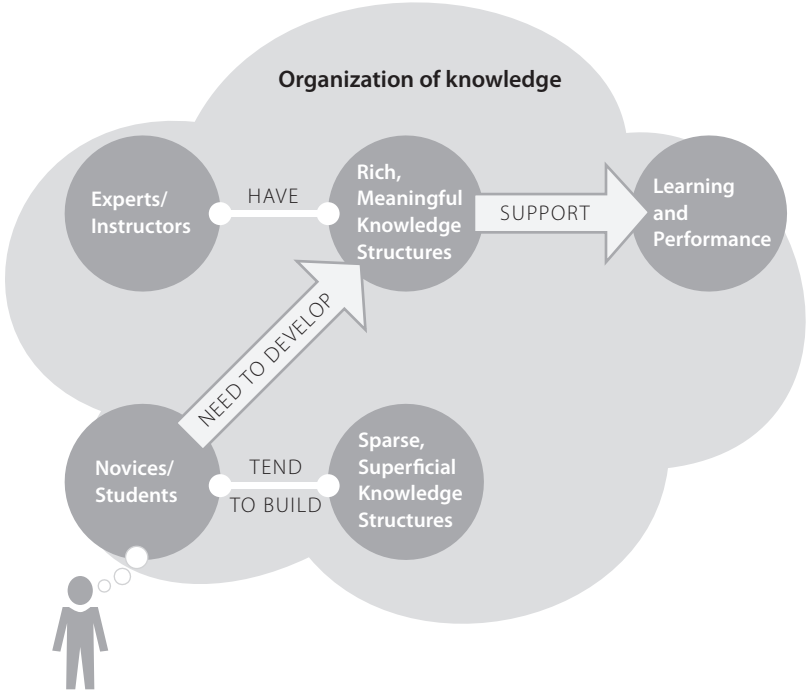

Figure 2.1. Differences in How Experts and Novices Organize Knowledge

organizations tend to differ in two key ways: the degree to which knowledge is sparsely versus richly connected, and the extent to which those connections are superficial versus meaningful. Although students often begin with knowledge organizations that are sparse and superficial, effective instruction can help them develop more connected and meaningful knowledge organizations that better support their learning and performance. Indeed, the second student in the example above shows progression in this direction.

WHAT DOES THE RESEARCH TELL US ABOUT KNOWLEDGE ORGANIZATION?

As a starting point for understanding how knowledge organizations differ and the consequences of those differences, it helps to consider how knowledge organizations develop. This is addressed in the section below. The remaining sections then elaborate on two important ways that experts' and novices' knowledge organizations differ and review research that suggests how novices can develop knowledge organizations that better facilitate learning.

Knowledge Organization: Form Fits Function

People naturally make associations based on patterns they experience in the world. For instance, we tend to build associations between events that occur in temporal contiguity (for example, a causal relationship between flipping the switch and a light turning on), between ideas that share meaning (for example, a conceptual relationship between fairness and equality), and between objects that have perceptual similarities (for example, a category-member relationship between a ball and a globe). As these associations