What Are the Qualities of Understanding?

Veronica Boix Mansilla and Howard Gardner

In Teaching for Understanding (TfU) classrooms, students are invited to put their understanding into action. Their performances allow teachers to assess and orient their progress toward achieving understanding goals. As teachers confronted the challenge of assessing their students' work, we recognized the need for a more specific definition of understanding. What does it mean to understand a historical event in depth? What qualities of understanding can teachers expect from students who are investigating a natural phenomenon? In their questions we saw the need for more detailed guidance to assess students' understanding. Together we engaged in the process of developing a theoretically grounded yet practical conception of students' understanding within and across disciplines. We pondered the question, "What qualities are embodied in deep understanding?

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In a climate of educational reform, debates around national standards, and cries to go back to the basics, multiple definitions of understanding live side by side. Some educators value the sophistication embodied in higher-order calculus operations; others stress the practical use of math to solve a problem of urban traffic. Some emphasize detail and precision in an account of the civil rights movement; others favor a critical analysis of the contrasting perspectives from which a story about the time may be told. Such different accents reflect the diverse interest groups in societies, the ways people interpret the world in which they live, and their diverse assumptions about the enculturation of youngsters.'

Despite such differences in emphasis, most educators hope that qualities such as disciplinary accuracy, social relevance, and critical spirit will indeed be embodied in students' performances. Presupposing such consensual goals, the TfU project has developed an Understanding framework to assess students' work and orient their development. This framework features four dimensions and four levels of understanding that can be discerned in students' performances. The main goal of this chapter is to introduce this reflective tool. To do so, we focus on twotopics and ideal performances of understanding. Then we propose the Understanding framework as a tool to systematize the assessment of these exemplary performances. In the end we highlight some of the

challenges that teachers may face in their efforts to use the framework in their classrooms.

Examining Students' Understanding

The quality of students' understanding rests on their ability to master and use bodies of knowledge that are valued by their culture. More specifically, it rests on their ability to make productive use of the concepts, theories, narratives, and procedures available in such disparate domains as biology, history, and the arts. Students should be able to understand the humanly constructed nature of this knowledge and to draw on it to solve problems, create products, make decisions, and in the end transform the world around them. Put differently, students should use knowledge to engage in a repertoire of performances valued by the societies in which they live.

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Students may perform their understanding in areas such as trade, sports, or the arts as well as in more scholarly disciplines such as history, math, and science. Education in the former domains has historically focused on learners' performances (such as producing a piece of furniture, swimming a race, singing a song). In contrast, education in the disciplines has tended to emphasize accumulation of information in the student's mind. Drawing on the model that has long been favored in the crafts, our work supports its development in more scholarly domains. In light of the specific challenge educators face in re-conceptualizing understanding in the disciplines, analysis in this chapter focuses on one example in history (U.S. industrialization in the nineteenth century) and one in science (genetic damage and cell growth). To illustrate such analysis we have created composite examples that bring together several students' most accomplished performances in TfU classrooms. Each composite was designed to represent the various dimensions of understanding portrayed in the Understanding framework and is occasionally enriched with features of performances portrayed in the developmental literature.

Understanding in History

Consider this example: the industrialization process that took place in the United States during the last half of the nineteenth century, transforming the modes of production and distribution of goods.

The Industrial Revolution: Disciplinary Background

Modern concepts of progress can be traced in part to the striking changes in transportation, manufacture, and communication brought about by the Industrial Revolution. This tumultuous process inspired abundant and often conflicting accounts of the period. Some authorities emphasize labor movements and working conditions; some highlight technological and macroeconomic growth; still others focus on the ideology underlying people's work ethics. These historical narratives also vary in their overall assessment of the development of industrial societies. Some portray it as a process of growth and progress; others characterize it in terms of long-term improvement of

standards of living; still others construe it as a process of severe deprivation and profound social costs. In all cases historians' accounts of industrialization render homage to the

complexity of this process. Usually they avoid linear or stereotyped representations and highlight continuities as well as changes over time.

Knowledge about industrialization emerges from careful interpretations of texts and documents that remain from the period, levered by accounts or interpretations proposed by other disciplinarians in more recent times. Narratives about industrialization go beyond describing specific events (such as strikes, migrations, or policies); they explain them by scrutinizing people's worldviews and motivations for their actions. Such explanations would be incomplete if they disregarded the broader social and economic conditions that shaped and constrained these people's actions at the time. In most cases the richness of these explanations emerges from taking into account contrasting perspectives on the problem ®¢ for example, those of the industrialists and those of immigrant workers.

In the discipline of history, narratives organize and give meaning to isolated information about the past. They propose interpretive theses that lend coherence to events. For instance, factual information such as the tripling of American per capita income between 1870 and 1910 or the details of unhealthy working conditions are devoid of significance if detached from the broader theses they support ®¢ that industrialization resulted in a higher concentration of wealth toward the end of the century in the United States or that the country's leading role in the world economy in the early twentieth century was in part due to its macroeconomic growth. Conversely, these theses would not cohere without the examples that back them up.

Accounts of industrialization vary not only in the way their authors go about investigating or interpreting the past but also in the purposes they serve. Some accounts aim to convince readers that values and worldviews such as class consciousness, for example, are shaped (or determined) by the social and economic circumstances in which people live, such as unemployment and economic recession in 1883. Another argument aims to orient individuals' behavior by highlighting the transformative power of a few industrial leaders at the time, portraying their attitudes, visions, and commitment as those of exemplary human beings. Historical accounts of one or another type do more than tell a story about the past; they help individuals reinterpret their present and orient their future.

Understanding these accounts in depth entails grasping their functional or pragmatic dimension as well.

Introducing Maria: A Portrait of Developing Understanding

Imagine a ninth-grade student, Maria. During a unit on industrialization, she carried out a project in which she studied the *biog*raphy of a captain of industry, George Pullman. Her inquiry was motivated by a question of interest to her: "How does someone get to be an industrial leader?" Our imaginary student examined the personalities and visions of some captains of industry. In addition her class studied multiple aspects of the rapidly changing society, such as migration patterns, technological improvements, working conditions, and productivity. In her final essay Maria focused on the social, political, and economic conditions that led to the need for a strong and determined innovator. The following excerpt portrays Maria's understanding in her project.

You see, the books I read were making Pullman look like he was Mr. Perfect, like he never made mistakes. Only one book was different, because it was about the big [Pullman] strike.... You just couldn't believe these stories. When I was reading I thought that maybe writers write these books because they need some gods, some models to look up to. Maybe they want you to believe that the industrial leaders were great people, and expect you to respect all leaders.

But I think you really needed to look at what was happening then to understand how somebody like Pullman got to be so important.... There were a lot of changes going on, a lot of new things started to happen, like the railroad and the factories with machines. You know, a lot of people thought that kind of a miracle was happening because of all these inventions and all the changes. But they were confused too. The cities were growing, life was fast, business was getting bigger. If somebody owned a little store, they could turn it into a factory or a big department store! They could send the stuff they made all over the country with the new railroads. People were getting excited and open minded. But not everything was so great! If you went to a factory at the time you wouldn't believe it. They were filthy; little kids had to work more than ten hours a day. It was really hot and the machines were dangerous! Farmers or people who made crafts or things had to move into the city slums. They had to work twelve hours a day just to survive.

I saw a book that had some pictures of real labor union pamphlets in it. The pamphlets showed and talked about how bad the factories were for the workers. The point of the essay I wrote is that Pullman was very successful when he started partly because he was generous. But mostly because he came up with the idea of the factory town when many people were looking for jobs and people were willing to try something new. It was also a time when people were very needed to work in the factories. Later, when the recession began to hit, business owners like him had to cut wages and fire a lot of people. The workers began to change their minds. They felt more united as workers and they organized the big Pullman strike in 1886 to force Pullman to cut their workday to eight hours. That was the beginning of the end of Pullman.

The Qualities of Maria's Understanding

Maria demonstrates important qualities of understanding. She has moved beyond stereotypical views of industrialization as a time of linear progress led by a few captains of industry that is usually perceived as the only leading force transforming American society. Instead, her account balances progress and conflict in ways that resemble a disciplinarian's practice. Maria demonstrates her ability to place individual facts, such as the creation of the factory town, within the broader framework of economic and lifestyle changes at the time. She is able to move flexibly between concrete examples (for instance, shop owners' and artisans' contrasting experiences) and broader, more conceptual interpretations (for example, industrialization as a complex process affecting different people in different ways).

By describing Pullman's success and failure, Maria demonstrates her ability to grasp continuities and changes over time-a central feature of historical inquiry. Furthermore, she demonstrates her ability to build historical explanations that involve human intentionality, such as people's openness to innovation and workers' growing class consciousness. Her explanations also involve broader related socioeconomic conditions, such as unemployment and economic recession. Maria enriches her account by considering multiple perspectives of the time, such as those of tradesmen, farmers, and artisans, although she does not recognize individual differences among people within these social groups. Her reference to pamphlets

as sources of reliable evidence for her claims completes our picture of Maria as a student who has begun to understand how historical knowledge is built and validated.

Finally, it is worth noting that Maria appreciates that historical accounts are written with a purpose in mind ®¢ to create social myths, to validate certain social groups. She sees herself as writing an account of the past that conveys a message as well, that is, that individual actions like the creation of the Pullman town need to be seen in the broader context of the circumstances in which they occur.

Understanding in Science

Now consider a second story, this one drawn from the biological sciences**.**

Understanding Genetic Damage: Disciplinary Background

Genetic damage refers to the alteration of the information-carrying deoxyribonucleic acid in cells' genes. Such alterations can be caused by chemicals contained in drugs and food and by other environmental factors such as ultraviolet (UV) light or other forms of radiation. Some mutations are inconsequential, but others modify the cells' shape, metabolism, or growth cycle. Because the genetic information is altered, mutations also affect subsequent generations of the damaged cells.

Understanding genetic damage entails understanding that genetic information encodes enzymes that control most aspects of cell growth. In complex organisms, cells grow while in constant communication with other cells and their environment. Healthy cells maintain a very delicate balance between growing and ceasing growth. During finely tuned cycles of growth, new cells develop increasingly specialized functions, culminating in the formation of the mature tissues of an organism. In some cases a cell's genes are damaged in a way that causes uncontrolled cell growth, frequently resulting in a tumor. Because this phenomenon has been tied to cancer among adults and malformation in unborn infants, understanding the mechanisms of cellular growth under conditions of genetic damage has become a priority for biological researchers.

A central premise underlying the construction of scientific knowledge is that models and theories about phenomena such as genetic damage or cell growth are constructed and stand in relation to bodies of empirical evidence. Relatedly, scientific facts (for example, alteration of growth balance in a particular cell) stand in relation to, and are organized and interpreted by, one or more theories. In their attempts to explain the mechanisms of cell growth and genetic damage, scientists develop models of growth and damage that are validated by standards of adaptability, stability, and internal consistency ®¢ that is, whether these models account for phenomena in the world, maintain their structure in the face or persistent testing, and avoid contradictory assertions.

Scientific models or theories emerge throughout a process that entails generating hypotheses, testing them experimentally, and interpreting findings. They provide the basis to interpret new information, and reciprocally, new information is examined in order to test and revise these theories.

Once sufficiently tested, models are often communicated in the form of diagrams that highlight particular structural and functional features of a process like genetic damage or cell growth. These diagrams convey powerful qualitative descriptions of the phenomenon. In contrast, changing patterns of growth are typically represented by graphs that summarize quantitative informaútion about the process.

Introducing Charlotte and Andrew: A Portrait of Developing Understanding

Let us now introduce two other exemplary performances of understandings, those of ninth-graders Charlotte and Andrew. Imagine that their teacher detected their strong motivation to explore genetic damage and invited them to design an experiment to test the hypothesis that UV light causes cell mutation. In the following dialogue they discuss the design of an experiment to test the effects of UV light from the sun on living yeast cells.

Charlotte: Let me see if we have the model right: when cells are mutated for some reason ®¢ radiation or chemicals or something like that ®¢ the genetic information in some of the cells gets damaged. So when these mutated cells

reproduce, the new cells have features that the old healthy cells didn't have. Okay?
Andrew: Yeah.... But we wanna test something else.... Whether UV light makes mutations in our yeast cells.
Charlotte: Yeah, sure. The thing is that we gotta have a picture in our head to see what we can get ®¢ see? ®¢ to imagine what results we're gonna get. Let's say we give a lot of sun to this group of cells here, and let them grow colonies. We'll have to keep some cells in the dark too. So if the sun affects the genetic information, the cells in the colonies have to be different in some way from our controls in the dark. You know.
Andrew: So ... if the light mutates some cells the colonies will get red, like we saw in the experiment on food preservatives. Remember?
Charlotte: You're right!
Andrew: You know, I'm thinking when we write the report for this whole thing someone may ask how we really know that the light was making a difference and that it wasn't just coincidence or another thing.
Charlotte: Hmm ...
Andrew: Guess we've got to be careful and control all the variables ... temperature, number of cells, the cells we pick and stuff.
Charlotte: We can also try different timing. Like we give different amounts of UV light time. So when we expose the colonies longer they should get more red than ...
Andrew: I see ... than the cells that are under the light just a little bit. We can make a two-entry chart. We can put "time under UV light" on one side and "number of red colonies" on the other.
Charlotte: Or maybe one of those curves would help! I'll make the graph when we're done.
Andrew: The other thing we can say in our report is that scientists study this not only because they want to know more about cells and how they get damaged, but also because they know that this is connected to cancer.
Charlotte: So, maybe we can find some of that and put in some piece about taking care of your skin and not letting UV light damage it too much!

The Qualities of Charlotte's and Andrew's Understanding
The dialogue just recounted reveals clear qualities of understanding. Both students demonstrate their ability to use a rich mental model of genetic damage. They describe some of the mechanisms involved in cell damage on the basis of which they are able to predict the effect of exposure to UV light. Although simple, their model of genetic damage mirrors those currently accepted in the discipline.

These students question their hunches with healthy skepticism and use methods of scientific inquiry such as variable control and experimental design to build warranted knowledge about mutation in yeast. Furthermore, they go beyond intuitive or *unschooled* inductivist-empiricist epistemologies of science, where knowledge is built through direct

observation of the world. Instead, the students approach their empirical observations through the lens of a model of cell damage that will shape their interpretation of what they see. Collecting and classifying data is not a mechanical endeavor, nor is building hypotheses a matter of producing isolated guesses detached from the theories that organize their thinking. Charlotte and Andrew's understanding goes beyond the algorithmic conception of the scientific method that dominates traditional science education.8

Charlotte and Andrew are attentive to the fact that scientific knowledge is made public and needs to convince its various audiences. Andrew puts himself in his readers' position and anticipates their skeptical concerns. The students reflect about distinctive ways to summarize their results. Furthermore, although they still draw unfounded implications from their limited experimental results to complex problems like cancer and skin care, these students are able to grasp the scientific and social relevance of studies in genetic damage (that is, to explain the mechanisms of damage and ultimately to contribute in part to the broader enterprise of preventúing cancer and birth defects). They begin to understand science as a purposeful human endeavor.

Systematizing Qualities of Understanding

The composite performances of understanding just portrayed reveal sophisticated understandings. In each case the examples reúspond to distinct disciplinary endeavors: in history, interpretive inquiry and reliance on remnants of the past and primary sources;

in science, experimental research and reliance on direct observation of highly controlled phenomena. Although bearing distinctive disciplinary traces, these performances also share some common patterns: students use a rich, detailed, and organized knowledge base; they draw on the methods and conventions of the disciplines to build and validate what they know; they attend to the social, scientific, or medical relevance of what they learn; and they care about the ways in which knowledge is shared with others. How can these qualities be systematized in a way that honors their disciplinary specificity but generates a language to talk about understanding across domains?

The Origins of a Framework

Identifying qualities of good understanding is not a new undertaking. Over time, disciplines like psychology and epistemology have sought to define such qualities in systematic ways. In a parallel fashion, communities of practitioners in disciplines, trades, and professions define and progressively refine the standards of quality for their products and practices. In so doing, these communities define the understanding that is available in a society at a given time. Capitalizing on this expertise, the Understanding framework introduced in this chapter has its roots in four principal sets of authorities.

First, disciplinary experts such as historians and biologists contributed detailed accounts of generative topics, such as, "Did industrialization mean progress?" and "How do cells

grow?" Their work provided exemplary cases of rich, accurate, and organized knowledge bases and proficient use of forms of communication.

Second, philosophers of the disciplines, such as Thomas Kuhn and Joseph Schwab in science and David Carr, Jacques LeGoff, and Paul Ricoeur in history,' enriched understanding of the processes of inquiry in these domains-for example, designing experiments, controlling variables, and interpreting empirical evidence, as well as defining significant historical events, avoiding anachronism, and writing narratives that account for continuity and change in time. Their work underscores the role of healthy skepticism and methúods in building warranted understanding.

Third, philosophers interested in knowledge more broadly, such as Jurgen Habermas and Agnes Heller,10 and those specifically interested in curriculum, such as John Dewey,

Paul Hirst, Philip Phenix, and (again) Joseph Schwab, informed our understanding of the organization of knowledge in various domains and the relationship between disciplinary knowledge and everyday life." In most of these cases scholars emphasize the possible uses and limitations of knowledge for solving problems, making decisions, and reinterpreting and transforming the world and highlight the intentional and interest-driven nature of inquiry. Their work enriched the conception of understanding as a performance capacity.

Fourth, cognitive and developmental psychologists, such as Mario Carretero, Peter Lee, Peter Seixas, and Samuel Wineburg12 in history and Susan Carey, Lawrence Kohlberg, and William Perry13 in other domains informed our work by defining the obstacles and possibilities that students face when moving from unschooled toward *disciplinary* understanding.14 Their studies were particularly relevant in formulating different levels of understanding.

The review of these sources allowed us to outline an initial conceptual portrait of qualities of understanding that we tested and enriched with an analysis of thirty-five students' reflections about understanding in four domains: English, math, science, and history. Our team of teachers and researchers assessed a series of students' videotaped reflections, identifying qualities of understanding that they valued, using some of the conceptual qualities originally portrayed, and reshaping them to accommodate the qualities emerging from the students' work. The TfU Understanding framework emerged as a result of this systematic dialogue between theory and data.

Four Dimensions of Understanding

To portray qualities of understanding systematically ®¢ in ways that are both respectful of disciplinary specificities and valid across domains ®¢ the Understanding framework highlightsfour dimensions of understanding: *knowledge, methods, purposes,* and *forms.* Within each dimension the framework describes four levels of underústanding: *naive, novice, apprentice,* and *master.*

Knowledge
The knowledge dimension assesses the extent to which students have transcended intuitive or unschooled perspectives and the degree to which they can move flexibly between examples and generalizations in a coherent and rich conceptual web.

Early in life students build powerful theories about matter, about society, and about themselves. Though imaginative, these theories often conflict with the versions worked out over the centuries by knowledgeable people in domains like history, science, and the arts. Unschooled beliefs are robust even after years of schooling. In some cases they remain part of commonsense understanding of the world15 ®¢ an understanding that is typically oriented to the practical, tied to the immediacy of the experience, local, egocentric, and validated by virtue of belonging to the generic collection of assumptions that a culture shares as "obvious."16 Refining, transforming, or replacing these early intuitions is a central challenge students face when they aim at understanding the world around them in depth.

For example, in talking about industrialization, students like Maria naturally perceive the twelve-hour workdays, low wages, and poor conditions as unfair or inhumane. Because it resonates with experience in current postindustrial societies, few would question or problematize this commonsensical claim. However, to be more historically sound, a disciplinary revision describes the degree to which workers themselves envisioned their working conditions as inhumane and how their perceptions changed over time. Such a disciplinary approach considers the details of the workers' experience and places them in a broader interpretation of the period.

In the examples of students' performances Maria goes beyond oversimplified portraits of industrialization, moving flexibly among a variety of human experiences such as those of factory workers and farmers. She provides vivid examples to support a more general thesis that the impact of industrialization varied by social group. Similarly, in the science example Charlotte reviews her understanding of the process and phases of genetic damage prior to engaging in experimental design. In her review, concepts like mutation, genetic information, and cell reproduction are integrated in a flexible system that will orient her interpretation of results.

Summary of Knowledge Dimension Criteria

Transformed intuitive beliefs. To what degree do students' performances show that warranted theories and concepts in the domain have transformed their intuitive beliefs? *Coherent and rich conceptual webs. To* what degree can students reason within richly organized conceptual webs moving flexibly between details and overviews, examples and generalizations?

Methods

The methods dimension recognizes that knowledge about the past, about nature or about society, contrasts with commonsense beliefs or mere information in that it is not readily available in the world to be picked up naturally and simply stored in individuals' minds. Knowledge results rather from a careful process of inquiry according to criteria that are publicly debated among communities of knowledgeable people in specific domains. Specifically, the methods dimension assesses students' ability to entertain healthy skepticism about what they know or what they are told as well as their use of reliable methods for building and validating claims and works as true, morally acceptable, or aesthetically valuable.

Over the years experts in various domains have developed methods and procedures that were tailored to build understanding of the specific kinds of phenomena they addressed. Like findings and theories, methods and validation criteria are publicly debated and agreed upon. They constitute individuals' most valid tools to build an understanding that goes beyond immediate and idiosyncratic experience and common sense. Understanding the foundations on which knowledge is constructed allows students to see why, amidst the infinite variety of accounts of problems like industrialization or genetic inheritance, only some are selected as fruitful, valid, and promising by knowledgeable people immersed in these issues."

Experts in domain-specific cognitive development have documented the distinctive challenges students face in their attempts to grasp methods, procedures, and criteria to build knowledge in different domains. In science, for example, students often tend to equate experiments with recipe-like procedures that are followed to attain a certain result. When confronted with contrary evidence, students often deny it, holding on to their initial

beliefs. The challenge these students face is to understand the logic of hypothesis testing that governs experimental design. They need to understand that experimental design is driven by theories about the phenomúena they address and that experiments are designed to test whether their hypotheses are correct, not to prove that they are.

In contrast to biological phenomena, historical processes cannot be studied through experimentation and variable control. Understanding in history involves on one hand reconstructing people's motives and beliefs in a world that was different from ours but bears some resemblance to it and on the other hand reconstructing the institutions, social structures, and cultural practices in which they lived that defined the range of opportunities and constraints that guided, limited, and inspired their actions." Understanding historical actors entails grasping the nuances in their beliefs, their internal contradictions, and the possible tensions between people and their contexts. This quality of understanding has proven to be a challenge for students, who often fall into the temptation of rendering past actions ludicrous or incomprehensible by projecting present values and worldviews on them.19

Accounts of industrialization or genetic inheritance are not "what really happened or happens" but rather people's current unúderstanding of what is thought to have happened on the basis of specific modes of historical and biological inquiry. Accordingly, we claim that such topics cannot be detached from the modes of thinking and inquiry from which they emerge. Charlotte's and Andrew's understanding of genetic damage is deeply rooted in a process of experimental inquiry. They engage in such a process by designing experiments that involve hypothesis testing, control of variables, careful observation, and interpretation of results. They engage in a dialogue between theory and data whereby both the theory and the data are scrutinized and refined. Maria's performance embodies methods and procedures that are typically used in building historical knowledge, such as considering multiple perspectives on an event, building explanations that consider multiple causes, and identifying continuities and changes within a single process over time. In both cases rather than perceiving knowledge as unquestionable, easy-to-obtain information recorded in textbooks, students construct and validate trustworthy accounts.

Summary of the Methods Dimension

Healthy skepticism. To what degree do students display a healthy skepticism toward their own beliefs and the knowledge presented in sources such as textbooks, people's opinions, and messages in the media?
Building knowledge in the domain. To what degree do students use strategies, methods, techniques, and procedures to build reliable knowledge similar to those used by professional practitioners in the domain?
Validating knowledge in the domain. Are truth, good, and beauty dependent on authoritative assertions or rather on publicly agreed-upon criteria such as using systematic methods, providing rational arguments, weaving coherent explanations, or negotiating meanings through careful dialogue?

Purposes
The purposes dimension is grounded on the conviction that knowledge is a tool to explain, reinterpret, and operate on the world. This dimension assesses students' ability to recognize the purposes and interests that drive knowledge construction, their ability to use knowledge in multiple situations, and the consequences of doing so.

Knowledge in history and science, as well as in filmmaking or architecture, emerges from a dialectical relationship between human concerns and needs on the one hand and the bodies of knowledge and tools that are available to a society on the other. Far from being abstract formulations of unquestionable truths, knowledge in various domains emerges from essential questions about the world that are grounded on experience in everyday life (for example, Why do people get cancer, and how can it be prevented? How and why did the United States become a leading nation?). Inspired by these questions and interests, knowledge evolves through a process of reflection that satisfies publicly agreed-upon standards of validation. Completing a dialectic cycle, knowledge comes back to everyday

life in the form of warranted frameworks or conceptual tools that people use to reinterpret and transform their world.' By exploring the essential questions that drive knowledge construction, teachers and students can reflect about the reasons why certain topics are worth studying in schools.

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Accounts of U.S. industrialization, for instance, satisfy individuals' essential need to understand other people's lives and understand themselves. Where do city lifestyles come from? How have people dealt with rapid technological changes? Disciplinary answers to these questions respond to specific interests. Some explain the relationship between economic and population growth in a search for patterns that people may find in the future; others expand individuals' consciousness and experience by examining the increasing ambivalence women workers felt regarding child labor; still others focus on immigrants, women, or people of color in order to illuminate and legitimize previously silenced voices of the past, thus alerting people about important conflicts in societies today (such as gender, race, and labor)." In our examples Maria demonstrates her understanding of the Pullman biographies when she uncovers purposes underlying the idealized portraits of Pullman that she found: fostering a society's identity or validating a soúcial group's authority. Charlotte and Andrew show their ability to relate their research on UV light and cell damage to broader social concerns about cancer that motivate scientific inquiry and are part of everyday life and the media.

When understanding ceases to be information accumulated in the students' mind and becomes a charter for action, new aspects of understanding need to be taken into account. For example, educators need to consider students' ability to find occasions to put knowledge into play and their critical assessment of the consequences of doing so. Students like Charlotte and Andrew may spontaneously critique a local newspaper's article on cancer by noticing that claims about causes for cancer are weakly grounded in correlational studies. Students like Maria may spontaneously use their understanding of working conditions among workers in the past to address issues of human rights in modern societies. Once students show the ability to engage spontaneously in these kinds of performances beyond the classroom environment, they demonstrate ownership over their understanding.

Summary of the Purposes Dimension
Awareness of the purposes of knowledge. To what degree do students see essential questions, purposes, and interests that drive inquiry in the domain?

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Multiple uses of knowledge. To what degree do students recognize a variety of possible uses for what they learn? To what degree do students consider the consequences of using this knowledge?

Ownership and autonomy. To what degree do students evidence ownership and autonomy to use what they know? To what degree have students developed a personal position about what they learn?

Forms

Finally, a performance view of understanding pays special attention to the forms in which understanding is performed ®¢ the process by which it is communicated to others. The forms dimension assesses students' use of symbol systems (visual, verbal, mathematical, and bodily kinesthetic, for example) to express what they know within established genres or types of performances ®¢ for example, writing essays, performing a musical, giving a presentation, or explaining an algorithm. Because of its communicative nature, this dimension also emphasizes students' ability to consider audience and context as shaping forces in their performances.

Making knowledge public (as required by performances of understanding) necessarily involves the use of a language or symbol system. The quality of a performance is determined in part by the effectiveness with which students use such symbols; for example, spatial arrangements of the elements in a cell that are relevant for its functioning call for graphic representations. Typically, models of cell growth are depicted in diagrams that require abstract representations of its mechanism. Using visual symbols this way is a challenge for students who tend to spontaneously depict elements in the cell as they appear under the microscope."

Students' understanding is manifest in a variety of performances, such as writing an essay, giving a presentation, creating a song, or participating in a conversation. Each type or genre of performance requires that students use what they know according to the rules and criteria that govern that particular genre24 ®¢ oral presentations need to be clearly enunciated, well organized, and smoothly paced; songs need to combine musical composition with lyrics in aesthetically appealing ways.

Finally, performing understanding for others requires that students take into account their audiences and contexts. Young or novice students' performances often contrast with

those of masters in a domain because they communicate in egocentric ways, showing little flexibility to perceive and accommodate to different audiences. For example, students are often unaware of the degree to which their audience is or is not familiar with their topic and of social or ethnic backgrounds that will filter audience interpretation.

In our examples Charlotte and Andrew are planning to share their findings with a critical audience. They foresee critiques and address them in their work, and they select the modes of representation that suit the data to be presented: schematic graphs to illustrate their observations qualitatively, histograms and distributions to portray change over time. Because Maria's excerpt does not refer to the challenges she will face in writing a good story about industrialization or communicating her interpretations of the period to an

audience, little inference can be made about the quality of the form dimension of her understanding.

Summary of the Forms Dimension

Mastery of performance genres. To what degree do students display mastery of the genres of performances they engage in, such as writing reports, giving presentations, or preparing the stage for a play?
Effective use of symbol systems. To what degree do students explore different symbol systems effectively and creatively to represent their knowledge ®¢ for example, using analogies and metaphors, colors and shapes, or movements?
Consideration of audience and context. To what degree do students' performances show an awareness of their audience-that is, the audience's interests, needs, cultural backgrounds, or expertise? To what degree do they show awareness of the situation in which communication happens?

Four Levels of Understanding
The four dimensions illustrate the multidimensional nature of understanding. Whereas some dimensions may be more prominent than others in specific performances, deep understanding entails the ability to use knowledge in all the dimensions. Because the

depth of understanding may vary within each dimension, distinguishing weaker from more accomplished performances is necessary. It was with this goal in mind that we characterized the four prototypical levels of understanding per dimension: naive, novice, apprentice, and master.

Performances of *naive understanding are* grounded on intuitive knowledge. They portray knowledge construction as an unproblematic process of grasping information that is directly available in the world. In these performances students do not see the relationship between what they learn in school and their everyday lives; they do not consider the purposes and uses of knowledge construction. At this level performances show no signs of students' ownership of what they know. Performances of naive understanding are unreflective about the ways that knowledge is expressed or communicated to others.

Let us revisit our industrialization example to illustrate. Students' performances at a naive level tend to report imaginative ®¢ but incorrect accounts of the process. The grounds and origins of such accounts remain unquestioned. Any reference to the significance of industrialization will seem irrelevant to students at this level; their narratives are likely to be incoherent or egocentric.

Performances of *novice understanding* are predominantly grounded on the rituals and mechanisms of testing and schooling. These performances begin to interject some disciplinary concepts or ideas and to establish simple, often rehearsed connections among them. They portray the nature and purposes of knowledge construction as well as its

forms of expression and communication as step-by-step mechanistic procedures. The validation of these procedures depends on external authority rather than on rationally agreed-upon criteria developed within disciplines or domains.

At this level a story about industrialization mimics the textbook, incorporating concepts such as "captains of industry" or "labor unions." Prompted to justify the reliability of this account, students refer to their teacher's assessments, grades, or textbooks as unquestioned sources of validation. Essays at this level follow a structure that contains an introduction, body, and conclusion, but they still do so algorithmically, as steps in a protocol to be slavishly followed. When asked about the importance of understanding industrialization, students at this level tend to refer to its impact on their term grades and standardized test scores.

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Performances of *apprentice understanding* are grounded in disciplinary knowledge and modes of thinking. They demonstrate flexible use of disciplinary concepts or ideas. Knowledge construction is seen as complex, following procedures and criteria that are typically used by experts in the domain. With support, performances at this level highlight the relationship between disciplinary knowledge and everyday life, examining opportunities and consequences of using this knowledge. Performances at this level show flexible and appropriate expression and communication of knowledge.

Certain aspects of Maria's performance in our example indicate that she has achieved at least an apprentice understanding of industrialization. She demonstrates her ability to perform within standards of good historical practice in ways appropriate to a child of her age. She describes industrialization from different points of view; she moves flexibly between detailed information and interpretive generalizations: she is aware of the purposeful nature of historical narratives. Her ability to consider both historical actors' intentions as well as the social, economic, and political circumstances in which they lived confirms her tendency to see knowledge construction as a problematic process.

Finally, performances of *master understanding* are predominantly integrative, creative, and critical. Students at this level are able to move flexibly across dimensions, relating the criteria by which knowledge is built and validated in a discipline to the nature of its object of study or the purposes of inquiry in the domain. Knowledge construction is seen as complex, driven by often conflicting frameworks and worldviews, and emerging as the result of public argumentation within communities of practitioners in various domains. Students can use knowledge to reinterpret and act upon the world around them. Knowledge is expressed and comúmunicated to others in creative ways. Performances at this level often go beyond demonstrating disciplinary understanding; they may reflect students' critical awareness about the construction of knowledge in the domains. (That is, *metadisciplinary understanding* is the ability to combine disciplines in interdisciplinary performances of understanding.)

An important quality of Maria's performance of understanding is its integrated and critical nature. She goes beyond an apprentice level of understanding by drawing relationships across dimensions. For example, she notices that the purposes of certain

biographies (proposing societal models or reaffirming the power of a few) may orient the selection of sources and the focus of attention of a writer's work. The critical spirit of her understanding is manifest when she reflects about knowledge construction explicitly and proposes that individual-centered histories must be complemented with broader historical analysis (such as a social, political, or economic history of the period).

The framework of dimensions and levels of understanding proposed in this chapter is not a rigid representation of disciplinary understanding. Instead, it constitutes a conceptual tool, a framework to examine students' understanding and orient their future work. As a working tool, it needs to be adapted to the specific content, contexts, and levels of instruction in which it is used. (Summaries of these dimensions and levels of understanding appear in Tables 6.1 through 6.5 in the appendix at the end of this chapter.)

Conclusions

The TfU performance view of understanding defines understanding as the ability to use knowledge in novel situations. In so doing, the TfU framework proposes that knowledge becomes a reflective tool for making products, telling stories, solving problems, making judgments, and transforming everyday life. This conception of knowledge and understanding contrasts with a widespread view of disciplinary knowledge in schools, where disciplines are usually seen as collections of certified facts arranged under such labels as "math" or "history" ®¢ where students need to master these facts as a sign of their cultural literacy.25 In this tradition, American industrialization becomes a collection of events "that really happened," complemented with a list of causes and consequences and detached from its multiple interpretations as well as from its role in providing models of virtue and vice to shape national identity.

Re-conceptualizing knowledge in the disciplines as tools entails four major shifts away from this factual epistemology. First, it requires a shift in focus from isolated facts about the world to broader, richly organized conceptual networks of examples and generalizations that are currently accepted as warranted in the domains taught. Second, it requires that individuals see these ac counts as humanly constructed according to certain

commonly agreed-upon methods and criteria that render them reliable (such as naturalistic observation, interpretation of sources, and empathic understanding). Third, it requires attention to the purposes that motivate inquiry around specific problems and the uses to which the resulting bodies of knowledge can be put (such as explaining, predicting, and controlling nature, or developing class consciousness or national identity).

Fourth, it requires that individuals find appropriate ways to communicate and share knowledge (for example, by presenting supporting data for a claim, formulating an argument, or using the poetic power of a narrative). These four shifts embody the four dimensions of understanding presented in this chapter that far from being static and unrelated categories, interact dynamically in students' performances.

By proposing a four-dimensional Understanding framework, we invite teachers and students to ask new kinds of questions about topics like the Industrial Revolution or the mechanisms of genetic damage: What are the accounts of these phenomena that society holds as true? Why do people consider these accounts reliable? Why is it important to learn about this? How can students use what they know reflectively to orient their actions in everyday life and transform the world they live in? How can they best share what they understand? In Chapters Seven and Eight the dimensions and levels of the Understanding framework are used to shed light on these questions by revealing the qualities of understanding in students' work.