HOW LEARNING WORKS

7 Research-Based Principles *for* Smart Teaching

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How Learning Works

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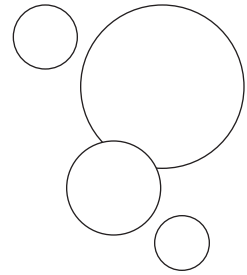


Introduction: Bridging Learning Research and Teaching Practice

> Learning results from what the student does and thinks and only from what the student does and thinks. The teacher can advance learning only by influencing what the student does to learn.
>
> HERBERT A. SIMON,[1] one of the founders of the field of Cognitive Science, Nobel Laureate, and University Professor (deceased) at Carnegie Mellon University

As the quotation above suggests, any conversation about effective teaching must begin with a consideration of how students learn. Yet instructors who want to investigate the mechanisms and conditions that promote student learning may find themselves caught between two kinds of resources: research articles with technical discussions of learning, or books and Web sites with concrete strategies for course design and classroom pedagogy. Texts of the first type focus on learning but are often technical, inaccessible, and lack clear application to the classroom, while texts of the second type are written in accessible language but often leave instructors without a clear sense of why (or even whether) particular strategies promote learning. Neither of these genres offers what many instructors really need—a model of

student learning that enables them to make sound teaching decisions. In other words, instructors need a bridge between research and practice, between teaching and learning.

We wrote this book to provide such a bridge. The book grew out of over twenty-nine years of experience consulting with faculty colleagues about teaching and learning. In these consultations, we encountered a number of recurring problems that spanned disciplines, course types, and student skill levels. Many of these problems raised fundamental questions about student learning. For example: Why can't students apply what they have learned? Why do they cling so tightly to misconceptions? Why are they not more engaged by material *I* find so interesting? Why do they claim to know so much more than they actually know? Why do they continue to employ the same ineffective study strategies?

As we worked with faculty to explore the sources of these problems, we turned to the research on learning, and from this research we distilled seven principles, each of which crystallizes a key aspect of student learning. These principles have become the foundation for our work. Not only have we found them indispensable in our own teaching and in our consultations with faculty, but as we have talked and worked with thousands of faculty from around the world, we have also found that the principles resonate across disciplines, institution types, and cultures, from Latin America to Asia. In our experience, these principles provide instructors with an understanding of student learning that can help them (a) see *why* certain teaching approaches are or are not supporting students' learning, (b) generate or refine teaching approaches and strategies that more effectively foster student learning in specific contexts, and (c) transfer and apply these principles to new courses.

In this book, we offer these principles of learning, along with a discussion of the research that supports them, their implications for teaching, and a set of instructional strategies targeting

each principle. Before briefly summarizing the full set of principles and discussing the characteristics they share and some ways that this book can be used, we begin by discussing what we mean by learning.

WHAT IS LEARNING?

Any set of learning principles is predicated on a definition of learning. In this book, we define learning as a *process* that leads to *change*, which occurs as a result of *experience* and increases the potential for improved performance and future learning (adapted from Mayer, 2002). There are three critical components to this definition:

1. Learning is a *process*, not a product. However, because this process takes place in the mind, we can only infer that it has occurred from students' products or performances.
2. Learning involves *change* in knowledge, beliefs, behaviors, or attitudes. This change unfolds over time; it is not fleeting but rather has a lasting impact on how students think and act.
3. Learning is not something done *to* students, but rather something students themselves do. It is the direct result of how students interpret and respond to their *experiences*—conscious and unconscious, past and present.

OUR PRINCIPLES OF LEARNING

Our seven principles of learning come from a perspective that is developmental and holistic. In other words, we begin with the recognition that (a) learning is a developmental process that intersects with other developmental processes in a student's life, and

(b) students enter our classrooms not only with skills, knowledge, and abilities, but also with social and emotional experiences that influence what they value, how they perceive themselves and others, and how they will engage in the learning process. Consistent with this holistic perspective, readers should understand that, although we address each principle individually to highlight particular issues pertaining to student learning, they are all at work in real learning situations and are functionally inseparable.

In the paragraphs below, we briefly summarize each of the principles in the order in which they are discussed in the book.

Students' prior knowledge can help or hinder learning.

Students come into our courses with knowledge, beliefs, and attitudes gained in other courses and through daily life. As students bring this knowledge to bear in our classrooms, it influences how they filter and interpret what they are learning. If students' prior knowledge is robust and accurate and activated at the appropriate time, it provides a strong foundation for building new knowledge. However, when knowledge is inert, insufficient for the task, activated inappropriately, or inaccurate, it can interfere with or impede new learning.

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

Students naturally make connections between pieces of knowledge. When those connections form knowledge structures that are accurately and meaningfully organized, students are better able to retrieve and apply their knowledge effectively and

efficiently. In contrast, when knowledge is connected in inaccurate or random ways, students can fail to retrieve or apply it appropriately.

Students' motivation determines, directs, and sustains what they do to learn.

As students enter college and gain greater autonomy over what, when, and how they study and learn, motivation plays a critical role in guiding the direction, intensity, persistence, and quality of the learning behaviors in which they engage. When students find positive value in a learning goal or activity, expect to successfully achieve a desired learning outcome, and perceive support from their environment, they are likely to be strongly motivated to learn.

To develop mastery, students must acquire component skills, practice integrating them, and know when to apply what they have learned.

Students must develop not only the component skills and knowledge necessary to perform complex tasks, they must also practice combining and integrating them to develop greater fluency and automaticity. Finally, students must learn when and how to apply the skills and knowledge they learn. As instructors, it is important that we develop conscious awareness of these elements of mastery so as to help our students learn more effectively.

Goal-directed practice coupled with targeted feedback enhances the quality of students' learning.

Learning and performance are best fostered when students engage in practice that focuses on a specific goal or criterion, targets an appropriate level of challenge, and is of sufficient quantity and frequency to meet the performance criteria. Practice must be coupled with feedback that explicitly communicates about some aspect(s) of students' performance relative to specific target criteria, provides information to help students progress in meeting those criteria, and is given at a time and frequency that allows it to be useful.

Students' current level of development interacts with the social, emotional, and intellectual climate of the course to impact learning.

Students are not only intellectual but also social and emotional beings, and they are still developing the full range of intellectual, social, and emotional skills. While we cannot control the developmental process, we can shape the intellectual, social, emotional, and physical aspects of the classroom climate in developmentally appropriate ways. In fact, many studies have shown that the climate we create has implications for our students. A negative climate may impede learning and performance, but a positive climate can energize students' learning.

To become self-directed learners, students must learn to monitor and adjust their approaches to learning.

Learners may engage in a variety of metacognitive processes to monitor and control their learning—assessing the task at hand, evaluating their own strengths and weaknesses, planning their

approach, applying and monitoring various strategies, and reflecting on the degree to which their current approach is working. Unfortunately, students tend not to engage in these processes naturally. When students develop the skills to engage these processes, they gain intellectual habits that not only improve their performance but also their effectiveness as learners.

WHAT MAKES THESE PRINCIPLES POWERFUL?

The principal strength of these seven principles is that they are based directly on research, drawing on literature from cognitive, developmental, and social psychology, anthropology, education, and diversity studies, and research targeting not only higher education but also K–12 education. Although, of course, this is not an exhaustive review and any summary of research necessarily simplifies a host of complexities for the sake of accessibility, we believe that our discussions of the research underlying each principle are faithful to the scholarship and describe features of learning about which there is widespread agreement. Indeed, several of our principles converge with those that others have delineated (Pittsburgh Science of Learning Center, 2009; American Psychological Society, 2008), a convergence that we believe attests to their salience.

Not only are these principles research-based, but as we have shared them with colleagues over the years, we have found that they are

- *Domain-independent:* They apply equally well across all subject areas, from biology to design to history to robotics; the fundamental factors that impact the way students learn transcend disciplinary differences.

- *Experience-independent:* The principles apply to all educational levels and pedagogical situations. In other words, although the pedagogical implications of a principle will be somewhat different for first-year undergraduate students in a lab environment as opposed to graduate students in a studio environment, the principle still applies.
- *Cross-culturally relevant:* Although the research we identified has been conducted primarily in the Western world, faculty colleagues in other countries have resonated with the principles, finding them relevant to their own classes and students. However, it is important to bear in mind that culture can and does influence how the principles should be applied as instructors design and teach their courses.

INTENDED AUDIENCES

This book is intended for anyone interested in understanding more about how students learn and in applying that information to improve instruction. This includes—but is not limited to—faculty members, graduate students, faculty developers, instructional designers, and librarians. It also includes K–12 educators. In addition, the principles outlined here are valuable for instructors at all experience levels. They can help new and inexperienced instructors understand the components of effective course design and classroom pedagogy. They can help experienced instructors troubleshoot problems or adapt effective strategies to suit new courses or student populations. They can also help highly successful and experienced instructors reflect on what makes their approaches and methods effective. Finally, these principles can enable faculty members to better support student learning without having to rely on outside experts (a benefit that is particularly valuable for faculty at campuses without teaching and learning centers).

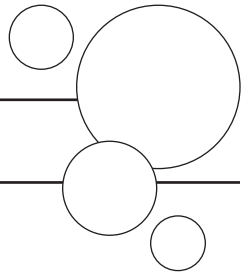
HOW TO READ THIS BOOK

Each chapter in this book begins with stories that represent teaching situations that we hope will strike readers as familiar. Although the instructors described in these stories are fictional, the scenarios are authentic, representing composites of real problems we have encountered over many years of consulting with faculty. We analyze these stories to identify the core problems or issues involved and use them to introduce the learning principle relevant to those problems. Then we discuss the principle in relation to the research that underlies it. Finally, we provide a set of strategies to help instructors design instruction with that principle in mind.

Because all of these principles combine to influence learning, no one principle stands alone. Consequently, the chapters can be read in any order. Moreover, the book can be read in conjunction with our Web site, which provides additional strategies, applications, sample materials, and resources. The URL is http://www.cmu.edu/teaching.

NOTE

1. Herb Simon was a university professor at Carnegie Mellon University and had joint appointments in the departments of psychology and computer science. While at Carnegie Mellon, Herb played a major role in the development of the Graduate School of Industrial Administration (renamed the Tepper School of Business in 2004), the Department of Psychology, the School of Computer Science, and the College of Humanities and Social Sciences. He was one of the founding fathers of the fields of cognitive psychology and artificial intelligence, and won the Nobel Prize in Economics in 1978 and the National Medal of Science in 1986. For many years (until his death), Herb served as a member of the Advisory Committee to the Eberly Center for Teaching Excellence. He was often heard paraphrasing this quote from Elliott Dunlap Smith, a past president of Carnegie Mellon University.



CHAPTER 1

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

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

CHAPTER 3

What Factors Motivate Students to Learn?

My Students Are Going to Love This—NOT

This past semester, I finally got to teach a course that relates directly to my area of interest. I put in a lot of time and energy this summer preparing materials and was really excited going into the semester. I used a number of seminal readings in Continental Philosophy and assigned a research project based on primary documents from the nineteenth and twentieth centuries. I thought that students would be excited by the topic and would appreciate reading some of the classic works. But it did not turn out the way I had hoped, and I was really disappointed by their work. With the exception of the two philosophy majors and the one student who "needed an A to get into graduate school," they were not at all interested in the readings and hardly participated in the discussions. In addition, they were not particularly inspired or creative in choosing research topics. Overall, they made little progress across the semester. I guess when it comes right down to it, most students do not much care about philosophy.

Professor Tyrone Hill

A Third of You Will Not Pass This Course

My colleague who usually teaches Thermodynamics was on leave for the semester, and I was assigned to take his place. I knew it would not be easy to teach this course: it has a reputation for being really hard, and engineering students only take it because it is required for the major. On top of that, my colleague had warned me that many students stop coming to lectures early on in the semester, and those who come to class often do not come prepared. It seemed clear that I needed a way to motivate students to work hard and keep up with the material. I recalled that when I was a student, any suggestion by the professor that I might not be up to the challenge really got me fired up and eager to prove him wrong. So I told my students on the first day of class, "This is a very difficult course. You will need to work harder than you have ever worked in a course and still a third of you will not pass." I expected that if my students heard that, they would dig in and work harder to measure up. But to my surprise, they slacked off even more than in previous semesters: they often did not come to class, they made lackluster efforts at the homework, and their test performance was the worst it had been for many semesters. And this was after I gave them fair warning! This class had the worst attitude I have ever seen and the students seemed to be consumed by an overall sense of lethargy and apathy. I am beginning to think that today's students are just plain lazy.

Professor Valencia Robles

WHAT IS GOING ON IN THESE STORIES?

In both of these stories, students fail to acquire and demonstrate the level of understanding the professors desire. In both cases,

CHAPTER 4

How Do Students Develop Mastery?

A Sum of Their Parts

I worked in industry for over twenty years before coming to academia, and I know how critical teamwork is, so in my Industrial Management course I assign a number of group projects in addition to individual projects. Students generally do well on their individual projects, and since the group assignments and individual assignments require more or less the same content knowledge, you would think that students would do even better on the group projects: after all, there are more people to share the work and generate ideas. Instead, it is just the reverse. Not only do my student groups fail to meet deadlines, but their analyses are also superficial and their projects lack internal coherence. I am not sure what the problem is, but at this point I am tempted to scrap the group projects and go only with individual projects. I just wish someone could explain to me why these groups are *less*, not *more*, than a sum of their parts.

Professor Fritz Solomon

Shouldn't They Know This by Now?

I just came from the second meeting of my acting class, and I have never felt so frustrated. This is an upper-level course, so by the time students get to my course they have already taken

a number of courses in speech, voice, and movement. In other words, they *should* have a solid grounding in the fundamentals. Yet they make the most elementary mistakes! To give an example, I assigned students an easy scene from a Tennessee Williams play, something they should be able to handle with ease. And yet, a good proportion of the class mangled the Southern accents, dropped props, or mumbled their lines. Not only that, but they completely disregarded two things I know their instructors have emphasized over and over again in the introductory classes: the importance of doing vocal warm-ups and phonetically transcribing all their lines. How can they not know this stuff by now? I know they have learned it, because I have sat in on some of the first- and second-year classes and have been impressed by their skills. So why do they seem to have forgotten everything when they get to my course?

Professor Pamela Kozol

WHAT IS GOING ON IN THESE STORIES?

The instructors in these two stories believe that their students have the skills and knowledge necessary to perform well on the assigned tasks, yet their students' performance is disappointing, and neither instructor knows why. What is happening in each case that can help explain why these students fail to meet their instructor's expectations?

In fact, the tasks these instructors have assigned may require more from students than the instructors realize, and their students may be less prepared than their instructors assume. In the first story, for example, Professor Solomon expects the quality of group projects to be higher than the quality of individual projects

CHAPTER 5

What Kinds of Practice and Feedback Enhance Learning?

When Practice Does Not Make Perfect ...

I teach a public policy course to juniors, and I believe strong communication skills are essential to moving up the ranks in the public sector. As a result, I require my students to write frequently. The three papers I assign focus on the different types of writing my students will potentially do: a policy briefing, a persuasive memo to their boss, and an editorial for a newspaper. I had expected the students' writing on these assignments to be at least decent because all of our students are required to take two writing courses in their first year. Then, when I saw the serious problems in their first papers, I thought at least I could help them improve. So I have been spending an enormous amount of time grading and writing margin comments throughout their papers, but it does not seem to be doing any good: the second and third assignments are just as bad as the first. As much as I think these assignments are useful because they prepare students for their future professional lives, I am ready to nix them because the students' writing is so poor and my efforts are bringing about little or no improvement.

Professor Norman Cox

They Just Do Not Listen!

Last semester, when I taught Medical Anthropology, the students' research presentations were all glitz and very little substance. So this time, because this project is worth 50 percent of their final grade, I tried to forewarn my students: "Do not be seduced by technology; focus on substantive anthropological arguments and create engaging presentations." And yet, it happened again. Last Tuesday, student after student got up in front of the class with what *they* believed to be engaging presentations—fancy fonts in their PowerPoint slides, lots of pictures swishing on and off the screen, embedded video clips, and so on. It was clear they had spent hours perfecting the visuals. Unfortunately, although their presentations were visually stunning, the content was very weak. Some of the students had not done thorough research, and those who did tended merely to describe their findings rather than craft an argument. In other cases, students' arguments were not supported by sufficient evidence, and most of the images they included were not even connected to the research findings. I thought I was clear in telling them what I wanted and did not want. What is it going to take to make them listen?

Professor Tanya Strait

WHAT IS GOING ON IN THESE STORIES?

In both stories, the professors and their students seem to be putting in time and effort without reaping much benefit. For example, Professor Cox makes lengthy comments on his students' writing but fails to see any improvement across assignments. Professor Strait's students spend an inordinate amount of time on aspects of the presentation that actually matter least to her,

CHAPTER 6

Why Do Student Development and Course Climate Matter for Student Learning?

End of Story

Yesterday in my Economics class, we were discussing an article about the cost of illegal immigration to the U.S. economy. The discussion was moving along at a brisk pace when one student, Gloria, began to intervene quite forcefully, saying the reading was biased and didn't represent the situation accurately. Another student, Danielle, responded: "Gloria, why do you always have to bring up race? Why can't we just discuss the figures in the articles without getting so defensive?" A third student, Kayla, who has been pretty quiet up to this point in the semester, said that, as far as she was concerned, illegal immigrants should be arrested and deported, "end of story." Her grandparents were Polish immigrants, she continued, and had come to the U.S. legally, worked hard, and made good lives for themselves, "but now this country is getting sucked dry by Mexican illegals who have no right to be here, and it's just plain wrong." At that point, the rest of the class got really quiet and I could see my three Hispanic students exchange furious, disbelieving looks. Annoyed, Gloria shot back: "Those 'illegals' you're talking about include some people very close to me, and you don't

know anything about them." The whole thing erupted in an angry back-and-forth, with Gloria calling Kayla entitled and racist and Kayla looking close to tears. I tried to regain control of the class by asking Gloria to try to depersonalize the discussion and focus on the central economic issues, but when we returned to the discussion I couldn't get anyone to talk. Kayla and Gloria sat silently with their arms folded, looking down, and the rest of the class just looked uncomfortable. I know I didn't handle this situation well, but I really wish my students were mature enough to talk about these issues without getting so emotional.

Professor Leandro Battaglia

No Good Deed Goes Unpunished

There's been a lot of discussion in my department about how to get more female students into Electrical Engineering. This is something I believe is very important, so I've gone out of my way to support and encourage the women in my classes. I know engineering can be an intimidating environment for women, so I always try to provide extra help and guidance to female students when they're working on problem sets in small groups. I've also avoided calling on women in class, because I don't want to put them on the spot. So you can imagine my frustration when a student reported to me a few weeks ago that one of my teaching assistants had made a blatantly derogatory comment during recitation about women in engineering. I've had a lot of problems with this TA, who has very strong opinions and a tendency to belittle people he doesn't agree with, but I was particularly unhappy about this latest news. I chastised the TA, of course, and gave him a stern warning about future misconduct, but unfortunately the damage was already done: one female student in that

recitation (who seemed particularly promising) has dropped the course and others have stopped speaking up in class. I braced myself for complaints on the early course evaluations I collected last week, and some students did complain about the sexist TA, but what really baffled me was that they complained about me too! One student wrote that I "patronized" female students while another wrote that the class was "unfair to us guys" since I "demanded more from the men in the course." I have no idea what to make of this and am beginning to think there's simply no way to keep everyone happy.

Professor Felix Guttman

WHAT IS GOING ON IN THESE TWO STORIES?

In both of the stories described above, unanticipated social and emotional dynamics in the classroom have complicated the learning experience. Although Professor Battaglia has assigned a reading that touches on a controversial topic, he expects his students to be able to discuss the material in terms of economic principles rather than personal experience and ethnic identity, which in his mind are mutually exclusive. What begins with an intellectual discussion of the reading quickly devolves into a highly charged emotional exchange about racial issues—in his mind, only marginally related to the course content—culminating in hurt feelings, discomfort, disengagement, and ultimately a complete collapse of the discussion. Professor Battaglia finds himself unable to rein in the chaos. The fracas that arises leaves him feeling helpless and wondering why students are unable to check their emotions at the door.

Professor Guttman's situation, however, is completely unrelated to his course content. Here we see a well-meaning instructor,

CHAPTER 7

How Do Students Become Self-Directed Learners?

The "A" Student

I was exhausted from reading and grading twenty-five papers over the past weekend, but I was glad to be able to hand them back so quickly. It was the first big assignment in my freshman seminar on immigration, and it required students to state an argument and support it with evidence from course readings and supplemental documents. After class, one of the students, Melanie, approached me and insisted that she needed to talk with me immediately about her grade (not about her paper, mind you!). Hers was a typical first paper in this course—it lacked a clearly articulated argument, and there was only weak evidence to support what I inferred was her argument. As we walked across campus toward my office, she began explaining that she was a "gifted" writer who had always received As on her high school English papers. She made clear to me that there must be some mistake in this paper's grade because her mother, a high school English teacher, had read the paper over the weekend and thought it was wonderful. Melanie admitted that she had started this assignment the night before it was due, but insisted that she worked best under pressure, saying, "That's just how my creative juices flow."

Professor Sara Yang

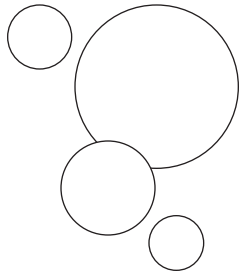
The Hamster Wheel

After I saw John's grade on the second Modern Chemistry exam, I couldn't help but ask myself, "How can someone attend every single lecture—sitting attentively in the front row—and go to every recitation and lab, no less, and still do so poorly on my exams?" I had explicitly told the students that my exams are designed to test conceptual understanding, and yet John seemed to be thrown for a loop. His first exam score had also been pretty low, but he wasn't alone in that, given students' first-exam jitters. By this time, however, I thought he would have learned what to expect. I asked John what had happened, and he too seemed perplexed. "I studied for weeks," he said, flipping open his textbook. I could hardly believe how much of the text was highlighted. The pages practically glowed with neon yellow. He went on to describe how he had re-read the relevant chapters multiple times and then memorized various terms by writing their definitions on flashcards. I asked where he had learned this approach to studying, and he explained that it had always worked for him when he used to prepare for his science tests in high school.

Professor Gar Zeminsky

WHAT IS GOING ON IN THESE STORIES?

On the surface, these stories seem quite different: Melanie starts her history paper at the last minute, whereas John studies hard (and harder) for weeks before his chemistry exams. However, both students perform well below their expectations without understanding why. As we analyze the details of each story, other issues emerge. We see that John has a set of study strategies—mostly involving rote memorization of facts and definitions—that were



Conclusion: Applying the Seven Principles to Ourselves

By now, the power of the principles described in the book should be apparent. These principles explain and predict a wide range of learning behaviors and phenomena and hence aid the design of courses and classroom pedagogy. Their interconnectedness should also be evident. Many of the problems students encounter when learning stem from an interaction of intellectual, social, and emotional factors. Therefore, their pedagogical solutions must address all these facets at once. This is achievable precisely because our principles work together to provide such solutions. It also means that the number of strategies we must master to be effective teachers is not infinite. In fact, although the specific strategies throughout this book vary from chapter to chapter, there are recurring themes among the strategies, such as collecting data about students, modeling expert practice, scaffolding complex tasks, and being explicit about objectives and expectations. These basic themes jointly address cognitive, motivational, and developmental goals. For instance, being explicit about one's learning objectives and grading criteria helps students see the component parts of a complex task and thus allows them to target

their practice and move toward mastery. It also serves a motivational function because it increases students' expectations of success at the task, and it even impacts the learning climate by fostering a sense of fairness.

What is perhaps less evident is that these principles of learning apply to instructors as well because, when it comes to teaching, most of us are still learning. Teaching is a complex activity, and yet most of us have not received formal training in pedagogy. Furthermore, teaching is a highly contextualized activity because it is shaped by the students we have, advancements in our respective fields, changes in technology, and so on. Therefore, our teaching must constantly adapt to changing parameters. Although this realization can be overwhelming for some, it can also help us reframe our approach to improving our teaching because it means that we need not expect a static perfection, but a developing mastery of teaching. Learning to improve one's teaching is a process of progressive refinement, which, like other learning processes, is informed by the learning principles set forth in this book. This concluding chapter applies our seven learning principles to the process of learning about teaching. We highlight each principle's implications to learning about teaching. Just as in the previous chapters, we consider each principle individually for ease of exposition, but the ideas stemming from the seven principles together are all interrelated.

Like students, we possess a lot of *prior knowledge,* upon which we draw consciously and unconsciously when we teach, and this prior knowledge affects further learning and performance. But as we have seen, prior knowledge can be insufficient, inaccurate, or inappropriate, in which case it will hinder further learning. For instance, as experts in our respective fields, we possess a wealth of content knowledge, but this alone is insufficient for effective teaching. Some of us also possess the misconception that good teaching is all about entertainment and personality, and

that to be a good teacher one must be outgoing and funny. Not only is this notion inaccurate but it is also problematic because it locks both introvert and extrovert teachers in narrow and rigid roles without much room for growth. Finally, although it is helpful to be mindful of our own experiences as learners, it would be inappropriate to presume that all our students will share the same experiences we do and that therefore whatever teaching methods worked for us should work for our students as well. As pointed out repeatedly throughout this book, we are different from our students in many important ways. One of the recurring strategies emphasized in this book involves collecting data about students to help inform our teaching practice. Seen in this light, learning about our students is a way to build on our prior knowledge by learning more about the context and using this information to tailor our teaching to our audience.

Of course, in conjunction with the knowledge we possess about teaching, we need to think about the *organization* of that knowledge. Many of us started our careers without a rich, integrated, and flexible network of knowledge about teaching. For example, it is fairly common to keep one's knowledge of teaching compartmentalized by course: these are the kinds of assignments that work better for this course, these are the kinds of policies that are necessary when teaching first-year students, and so on. This organization is born out of experience, but it does not make for a flexible and systematic way to think about teaching because it centers on surface features of the course. The principles of learning presented in this book offer a deeper, more meaningful structure for organizing one's knowledge of teaching and learning and for building on that knowledge. This will help, for instance, when planning a new course for a new audience.

But refining our teaching is not only a cognitive process. It is also important to consider our *motivation* to learn (and continue to learn) about teaching. Given our other professional constraints,

what will sustain our efforts to improve our teaching? As we have seen, motivation is broadly determined by value and expectancy. One thing that most instructors value is efficiency. We are all busy and have demands on our time, and working on our teaching taxes that limited resource. Therefore, it is important that the time investment pays off. Several of the strategies we offer in this book require a time investment up front, but they yield time savings later on, especially for future iterations of the same course. For instance, creating a rubric can be time-consuming, especially if you have never created one, but it also saves time later by streamlining the grading process and reducing student complaints—in addition to the learning benefits for students. On the expectation side, we are more likely to stay motivated if we set teaching goals for ourselves that are realistic, so that we are more likely to maintain confidence in our ability to achieve those goals. This may, for example, mean that we should concentrate on improving one or two aspects of our teaching in a given semester, rather than trying to address everything simultaneously. It also might mean that instead of making radical changes to a course, we attempt more incremental changes, reflecting on them as we go. Many successful, experienced instructors maintain that it takes at the very least three years of progressive refinement to build an effective course.

Realistic expectations are especially important because teaching is a complex skill. To develop *mastery* in teaching, we need to acquire its component skills, integrate them, and apply them appropriately. Of course, this requires that we first unpack the multifaceted task of teaching. For example, the ability to facilitate productive and engaging discussions requires several subskills: the ability to pose appropriate questions, listen empathetically, maintain flow, respectfully correct misconceptions, manage time effectively, and many more. Putting all these skills together is the ultimate multitask. That is why we need to acquire fluency in each of them so that we develop enough automaticity to reduce the

cognitive load that any one of them requires. Moreover, as with the development of mastery in any other domain, teaching requires learning when and where various teaching strategies and instructional approaches are applicable; for example, when one's learning objectives would be best served by group projects or case studies and when they would not, or when a multiple choice test is warranted and when it is not. In other words, refining our teaching practice requires that we transfer what we learn about teaching from one context to another, making adjustments as our courses, our students, our fields—and, indeed, ourselves—change.

Developing mastery in teaching is a learning process, and as such it requires the coupling of *practice and feedback.* As we have seen, for practice to be maximally effective, it should be focused on clear goals. In order to set appropriate goals for our teaching, we can be guided by timely and frequent feedback on what aspects of our courses are and are not working. Most institutions mandate end-of-semester evaluations in which students can give instructors feedback about their teaching, but that kind of feedback is not the most useful for direct improvement of our teaching practice because it happens at the end of the term. The best feedback is formative feedback throughout the semester. This feedback can come from sources such as early course evaluations, student management teams, colleagues, and teaching center staff. So, for instance, if students raise concerns about the organization of our lectures, this can help us focus our efforts on a particular goal to help us improve. Just as many of our students do not think of the homework as practicing specific skills, most of us do not think of our teaching as "practice." However, like our students, we learn most efficiently when we target the skills we most need to develop. If we think of teaching as deliberate, focused practice, in the hypothetical situation above we could decide to follow specific practices such as having an agenda for every lecture or making transitions between subtopics more explicit.

Thinking of teaching as progressive refinement raises the notion of *development,* which happens in the context of a given *climate.* What does this developmental process look like? First, instructors—like students—go through a process of intellectual development. We might begin at a stage where we are looking for the "right answer," the pedagogical magic bullet that will, say, achieve full student participation during classroom discussion. At some other stages, we might regard teaching solely as a matter of personal style and believe there is no better or worse way to go about it. At later stages we might realize that teaching is highly contextualized and think about the many decisions we need to make as educators in terms of student learning. Second, our identity as instructors also goes through developmental stages. We have to work to develop a sense of competence and autonomy in teaching, integrity, and purpose as educators, a productive way to relate to the students, and appropriate ways to express our emotions in the classroom. In advanced stages of intellectual and identity development, we might develop trust in our own style while being open to improvement. Because this developmental process involves us intellectually as well as socially and emotionally, the broader climate in which we learn about teaching matters. For instance, being in a department that really values teaching can be energizing. Conversely, the climate can be demoralizing in a department that does not adequately support efforts to improve teaching. As we have discussed, the climate will have an impact on us whether we realize it or not. However, if we realize that our immediate climate is affecting us negatively, we have a number of options. We can branch out and seek a more supportive climate by broadening our reach to colleagues in other departments, to the education section of the various professional associations, or to the teaching center on campus.

In this chapter, we have highlighted various aspects of learning about teaching using the learning principles as lenses of analysis. In general, all these principles can help us be more reflective—that is, metacognitive—about our teaching. As shown in this book, *self-directed learning* (metacognition) requires engaging in a cyclical process with several phases. Specifically, we need to carefully consider our own strengths and weaknesses in relation to our teaching, not only so we can play to our strengths but also so we can challenge ourselves to develop in areas in which we may need work. Moreover, since the task of teaching constantly changes (as our student population changes, as we teach new courses, as we revise old courses to include new material, as we try new approaches), we must continually reassess the task, plan an effective approach, monitor our progress, evaluate, and adjust. Just as many students do not naturally think of planning before they get started on a task, many instructors do the same with their courses. For instance, they construct the assessments for a course as an afterthought, instead of planning them to be in alignment with the course's learning objectives and instructional strategies from the beginning. Knowing that we are likely to skip some of the steps in the metacognitive cycle can help us be mindful of this tendency and compensate for it.

Finally, refining our teaching practice requires being aware of our core beliefs about teaching and learning. For instance, what do we believe is the purpose of our teaching? What do we believe about intelligence, ability, and learning? All these beliefs will impact our metacognitive cycle. For instance, if we think of teaching skill as a talent that one either has or lacks, we may not engage in the kinds of behaviors (for example, self-reflection, comparing strategies with colleagues, seeking professional development, and reading this book!) that might help us improve. Conversely, if we think of teaching as a set of skills one can develop and refine, it

makes sense to engage in progressive refinement and in the whole metacognitive cycle. This book is a start in that process and an invitation to keep thinking and learning about teaching, as we hope that the ideas presented here will be generative of more insights and more strategies as they are applied and refined over time.

APPENDIX A

What Is Student Self-Assessment and How Can We Use It?

One way to gather feedback on students' prior knowledge and skills is to ask them to assess their own level of knowledge or skill. The objective is to get an idea of the range of abilities and experience of the class as a whole, not to evaluate individuals. Questions can focus on knowledge, skills, or experiences that you assume students have acquired and are prerequisites to your course, things that you believe are valuable to know but not essential, and topics and skills that you plan to address in the course. Students' responses to such questions can help you calibrate your course appropriately or help you direct students to supplemental materials that will help them fill in gaps or weaknesses in their existing skill or knowledge base that may hinder their progress. The questions also help students focus on the most important knowledge and skills addressed by your course and access information from prior courses or experiences that apply to your course.

The advantage of a self-assessment instrument is that it is relatively easy to construct and score and, because it can be administered anonymously, it is low-anxiety for the student. The weakness of the method is that students may not be able to accurately assess their abilities. Generally, people tend to overestimate their

knowledge and skills. However, accuracy improves when the response options are clear and tied to specific concepts or behaviors that students can reflect on or even mentally simulate, such as being able to define a term, explain a concept, or recall specific kinds and qualities of experience, such as building or writing or performing in a specific context.

Exhibit A.1 presents some examples of questions and response items.

Exhibit A.1. Sample Self-Assessments

How familiar are you with "Karnaugh maps"?

a. I have never heard of them or I have heard of them but don't know what they are.
b. I have some idea of what they are but don't know when or how to use them.
c. I have a clear idea of what they are but haven't used them.
d. I can explain what they are and what they do, and I have used them.

Have you designed or built a digital logic circuit?

a. I have neither designed nor built one.
b. I have designed one but have never built one.
c. I have built one but have not designed one.
d. I have both designed and built a digital logic circuit.

How familiar are you with a "t-test"?

a. I have never heard of it.
b. I have heard of it but don't remember what it is.
c. I have some idea of what it is, but am not too clear.
d. I know what it is and could explain what it's for.
e. I know what it is and when to use it and could use it to analyze data.

How familiar are you with Photoshop?

a. I have never used it, or I have tried it but couldn't really do anything with it.

b. I can do simple edits using preset options to manipulate single images (e.g., standard color, orientation, and size manipulations).
c. I can manipulate multiple images using preset editing features to create desired effects.
d. I can easily use precision editing tools to manipulate multiple images for professional quality output.

For each of the following Shakespearean plays, place a check mark in the cells that describe your experience.

Play	Have seen a TV or movie production	Have seen a live performance	Have read it	Have written a college-level paper on it
Hamlet				
King Lear				
Henry IV				
Othello				

APPENDIX C

What Are Rubrics and How Can We Use Them?

A rubric is a scoring tool that explicitly represents the instructor's performance expectations for an assignment or piece of work. A rubric divides the assigned work into component parts and provides clear descriptions of different levels of quality associated with each component. Rubrics can be used for a wide array of assignments: papers, projects, oral presentations, artistic performances, group projects, and so on. Rubrics can be used as scoring or grading guides, and to provide formative feedback to support and guide ongoing learning efforts.

Using a rubric provides several advantages to both instructors and students. Grading according to an explicit and descriptive set of criteria (designed to reflect the weighted importance of the objectives of the assignment) helps ensure that the instructor's grading standards remain consistent across a given assignment. Furthermore, although they initially take time to develop, rubrics can reduce the time spent grading by reducing uncertainty and by allowing instructors to refer to the rubric description rather than having to write long comments. Finally, grading rubrics are invaluable in large courses that have multiple graders (other instructors, teaching assistants, and so on) because they can help ensure consistency across graders.

Used more formatively, rubrics can help instructors get a clearer picture of the strengths and weaknesses of their students as a group. By recording the component scores and tallying up the number of students scoring below an acceptable level on each component, instructors can identify those skills or concepts that need more instructional time and student effort.

When rubrics are given to students with the assignment description, they can help students monitor and assess their progress as they work toward clearly indicated goals. When assignments are scored and returned with the rubric, students can more easily recognize the strengths and weaknesses of their work and direct their efforts accordingly.

For sample rubrics, see Exhibits C.1, C.2, C.3, and C.4. For detailed information on how to construct a rubric, see Stevens and Levi (2005).

Exhibit C.1. Rubric for Class Participation

	A (Exemplary)	B (Competent)	C (Developing)	D/R
Frequency and Quality	Attends class regularly and *always contributes* to the discussion by raising thoughtful questions, analyzing relevant issues, building on others' ideas, synthesizing across readings and discussions, expanding the class' perspective, and appropriately challenging assumptions and perspectives	Attends class regularly and *sometimes contributes* to the discussion in the aforementioned ways.	Attends class regularly but *rarely contributes* to the discussion in the aforementioned ways.	Attends class regularly but *never contributes* to the discussion in the aforementioned ways.

SOURCE: Eberly Center for Teaching Excellence, Carnegie Mellon University.

Exhibit C.2. Rubric for Oral Exams

Dimensions	A (18–20 points) Exemplary	B (16–17 points) Competent	C (14–15 points) Developing	D/R
Overall Understanding	Shows a deep/robust understanding of the topic with a fully developed argument per the categories below	Shows a limited understanding of the topic, not quite a fully developed argument per the categories below	Shows a superficial understanding of the topic, argument not developed enough per the categories below	Shows no understanding of the topic and no argument per the categories below
Argument	Clearly articulates a position or argument	Articulates a position or argument that is incomplete or limited in scope	Articulates a position or argument that is unfocused or ambiguous	Does not articulate a position or argument
Evidence	Presents evidence that is *relevant* and *accurate* Presents *sufficient* amount of evidence to support argument	Presents evidence that is *mostly relevant and/or mostly accurate* Presents *limited* evidence to support argument	Presents evidence that is *somewhat inaccurate and/or irrelevant*, but corrects when prompted Does *not* present *enough* evidence to support argument, but augments when prompted	Presents *a lot of inaccurate and/or irrelevant* evidence Doesn't present enough evidence to support argument, even when prompted repeatedly

Implications	Fully discusses the major implications of the argument or position	Adequately discusses some of the major implications of the position	Discusses minor implications (missing the major ones) *or* does not discuss major implications adequately	Doesn't discuss the implications of the argument or position
Structure	There is logic in the progression of ideas	There are a few areas of disjointedness or intermittent lack of logical progression of ideas	Ideas are somewhat disjointed and/or do not always flow logically, making it a bit difficult to follow	Ideas are disjointed and/or do not flow logically, hence argument is very difficult to follow
Prompting	Did not have to prompt with probing questions at all	Prompted minimally (one or two probing questions)	Prompted a lot (a series of probing questions)	

SOURCE: Eberly Center for Teaching Excellence, Carnegie Mellon University.

Exhibit C.3. Rubric for Papers

	Excellent	Competent	Not Yet Competent	Poor
Creativity and Originality	You exceed the parameters of the assignment, with original insights or a particularly engaging style.	You meet all the parameters of the assignment.	You meet most of the parameters of the assignment.	You do not meet the parameters of the assignment.
Argument	Your central argument is clear, interesting, and demonstrable (i.e., based on evidence, not opinion). The claims made in the body of your paper clearly and obviously support your central argument. Your arguments and claims reflect a robust and nuanced understanding of key ideas from this course.	Your central argument is clear and demonstrable. The claims made in the body of your paper support your central argument. Your arguments and claims reflect a solid understanding of key ideas from this course.	Your central argument is demonstrable but not entirely clear. A few of the claims made in the body of your paper do not clearly support your central argument. Your arguments and claims reflect some understanding of key ideas from this course.	Your central argument is unclear or it is not demonstrable. The claims made in the body of your paper do not support your central argument. Your arguments and claims reflect little understanding of key ideas from this course.

Evidence	The evidence you use is specific, rich, varied, and unambiguously supports your claims. Quotations and illustrations are framed effectively and explicated appropriately in the text.	The evidence you use supports your claims. Quotations and illustrations are framed reasonably effectively and explicated appropriately in the text.	Some of the evidence you use does not support your claims. Some of the quotations and illustrations are not framed effectively or explicated appropriately in the text.	Little of the evidence you use supports your claims. Few of the quotations and illustrations are framed effectively or explicated appropriately in the text.
Structure	Your ideas are presented in a logical and coherent manner throughout the paper, with strong topic sentences to guide the reader. The reader can effortlessly follow the structure of your argument.	The reader can follow the structure of your argument with very little effort.	The reader cannot always follow the structure of your argument.	The reader cannot follow the structure of your argument.

(*Continued*)

Exhibit C.3. (*Continued*)

	Excellent	Competent	Not Yet Competent	Poor
Clarity	Your sentences are concise and well crafted, and the vocabulary is precise; the reader can effortlessly discern your meaning.	The reader can discern your meaning with very little effort.	The reader cannot always discern your meaning.	The reader cannot discern your meaning.
Mechanics	There are no distracting spelling, punctuation, or grammatical errors, and quotations are all properly cited.	There are few distracting spelling, punctuation, and/or grammatical errors, and quotations are all properly cited.	There are some distracting spelling, punctuation, and/or grammatical errors, and/or some of the quotations are not properly cited.	There are significant and distracting spelling, punctuation, or grammatical errors, and/or the quotations are improperly cited.

SOURCE: Eberly Center for Teaching Excellence, Carnegie Mellon University.

Exhibit C.4. Senior Design Project Rubric

Component	Sophisticated	Competent	Not Yet Competent
Research & Design Identifies project objectives based on general description and client requirements	All important major and minor objectives are identified and appropriately prioritized.	All major objectives are identified but one or two minor ones are missing or priorities are not established.	Many major objectives are not identified.
Identifies relevant and valid information to support decision-making.	All relevant information is obtained and information sources are valid. Design recommendations are well supported by the information.	Sufficient information is obtained and most sources are valid. Design recommendations are mostly supported by the information.	Insufficient information is obtained and/or sources lack validity. Design recommendations are not supported by information collected.
Generation and analysis of alternatives.	Three or more alternatives are considered. Each alternative is appropriately and correctly analyzed for technical feasibility.	At least three alternatives are considered. Appropriate analyses are selected but analyses include some minor procedural errors.	Only one or two alternatives are considered. Inappropriate analyses are selected and/or major procedural and conceptual errors are made.

(*Continued*)

Exhibit C.4. (*Continued*)

Component	Sophisticated	Competent	Not Yet Competent
Identifies relevant constraints (economic, environmental/safety, sustainability, etc.)	All relevant constraints are identified and accurately analyzed.	Most constraints are identified; some are not adequately addressed or accurately analyzed.	Few or no constraints are identified or some constraints are identified but not accurately analyzed.
Generates valid conclusions/decisions	Recommended solution is based on stated criteria, analysis, and constraints.	Solution/decision is reasonable; further analysis of some of the alternatives or constraints may have led to different recommendation.	Only one solution is considered or other solutions were ignored or incompletely analyzed. Many constraints and criteria were ignored.
Communication Presentation Visual aids Oral presentation Body language	Slides are error-free and logically present the main components of the process and recommendations. Material is readable and the graphics highlight and support the main ideas.	Slides are error-free and logically present the main components of the process and recommendations. Material is mostly readable and graphics reiterate the main ideas.	Slides contain errors and lack a logical progression. Major aspects of the analysis or recommendations are absent. Diagrams or graphics are absent or confuse the audience.

	Speakers are audible and fluent on their topic, and do not rely on notes to present or respond. Speakers respond accurately and appropriately to audience questions and comments.	Speakers are mostly audible and fluent on their topic, and require minimal referral to notes. Speakers respond to most questions accurately and appropriately.	Speakers are often inaudible or hesitant, often speaking in incomplete sentences. Speakers rely heavily on notes. Speakers have difficulty responding clearly and accurately to audience questions.
	Body language, as indicated by appropriate and meaningful gestures (e.g., drawing hands inward to convey contraction, moving arms up to convey lift, etc.), eye contact with audience, and movement, demonstrates a high level of comfort and connection with the audience.	Body language, as indicated by a slight tendency to repetitive and distracting gestures (e.g., tapping a pen, wringing hands, waving arms, clenching fists, etc.) and breaking eye contact with audience, demonstrates a slight discomfort with the audience.	Body language, as indicated by frequent, repetitive, and distracting gestures, little or no audience eye-contact, and/or stiff posture and movement, indicate a high degree of discomfort interacting with audience.

(*Continued*)

Exhibit C.4. (*Continued*)

Component	Sophisticated	Competent	Not Yet Competent
Team Work (Based on peer evaluation, observations of group meetings, and presentation) Delegation and fulfillment of responsibilities	Responsibilities delegated fairly. Each member contributes in a valuable way to the project. All members always attended meetings and met deadlines for deliverables.	Some minor inequities in the delegation of responsibilities. Some members contribute more heavily than others but all members meet their responsibilities. Members regularly attended meetings with only a few absences, and deadlines for deliverables were met.	Major inequities in delegation of responsibilities. Group has obvious freeloaders who fail to meet their responsibilities or members who dominate and prevent others from contributing. Members would often miss meetings, and/or deadlines were often missed.

Team morale and cohesiveness	Team worked well together to achieve objectives. Members enjoyed interacting with each other and learned from each other. All data sources indicated a high level of mutual respect and collaboration.	Team worked well together most of the time, with only a few occurrences of communication breakdown or failure to collaborate when appropriate. Members were mostly respectful of each other.	Team did not collaborate or communicate well. Some members would work independently, without regard to objectives or priorities. A lack of respect and regard was frequently noted.

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