Teaching Learning Processes—to Students and Teachers

*Pamela E. Barnett, Linda C. Hodges
Princeton University*

Our teaching and learning center serves faculty and graduate students as teachers and undergraduates as learners. Here we share the experiences of graduate student facilitators whom we trained to lead problem-solving skills workshops for undergraduates. Our aim was to help these graduate students see themselves as teachers of disciplinary thinking as much as of disciplinary content. However, they also began to reexamine their teaching beliefs and practices, recognize and respond to the needs of novice learners, and become more conscious of the demands of learning their disciplines. We offer this program as a model for developing future faculty.

As educational consultants in the McGraw Center for Teaching and Learning at Princeton University, we often work with graduate students and faculty as instructors, asking them to think about student learning as the purpose of their teaching. This process requires that instructors become more aware of how students learn. However, as experts in their disciplines, instructors are often unconscious of the processes that they themselves use to learn in their field and the differences between their approaches as experts and those of novice learners. We describe here a program that helped make instructors more aware of these processes and the necessity of teaching them directly. Even though this program

began with the aim of teaching undergraduates about learning processes, it resulted in shifts in instructors' beliefs about learning and teaching.

Our teaching and learning center, like some others, serves faculty and graduate students as teachers, as well as undergraduates as learners, and we have found that our work with the one constituency is informed and improved by our work with the other. In an attempt to promote greater interest in and relevance for our undergraduate academic skills workshops, we began offering a few sessions specifically for quantitative classes, using content from those classes to model the processes of problem solving in those disciplines. We enlisted the help of graduate student teachers of biology, economics, and engineering to provide content expertise for the workshops, but we trained them to lead sessions focused on student learning processes, rather than the content *per se*.

During that training, we discovered that in most cases we were asking these experienced instructors to adopt a different model of teaching in a discipline. We were asking them to dig deeper into processes of learning than they were generally accustomed to. Our aim was to help graduate students see themselves as teachers of disciplinary thinking and ways of learning as much as of disciplinary content. After participating in our program, graduate student facilitators were more likely to consider their students as learners and become more conscious of the demands of learning their disciplines. This change in thinking was not easy to elicit, however, even for reflective young teachers. When graduate students worked with a peer group of graduate students across science and engineering disciplines, they were more likely to examine and reconsider their beliefs about learning and teaching than when they worked with us alone.

Our experience has implications for training graduate students as future faculty. This initiative illustrates the importance of collaboration between teaching and learning center staff who work primarily with instructors and those who provide academic support services to undergraduates. When graduate students lead workshops designed explicitly to teach academic skills rather than content, they must focus on the processes required to learn in the discipline—a new approach for them. This new situation

opens great possibilities for their development as teachers. We argue that the combination of reflection and practice that these graduate student facilitators experience leads to promising shifts in teaching beliefs that may lead to changes in their own teaching practice.

The Nature of the Problem

Instructors face a number of unperceived challenges as they seek to facilitate student learning. For example, they rarely recognize the implicit knowledge required for successful learning, and thus they seldom explicitly teach academic skills. Expert scholars have so developed the learning strategies and habits of mind required by the discipline that they can mobilize them largely unconsciously. Think, for instance, of the expert problem solver who intuitively asks conceptual questions about a problem and its relationship to other, similar problems before embarking on computation. Or the social science scholar who writes questions and criticisms in the margins of texts or tables while reading. Although this unconscious mobilization of processes is the hallmark of expert scholars, these processes are often unfamiliar and invisible to the students they teach (Bransford, Brown, & Cocking, 2000; Schoenfeld, 1985; Simon & Simon, 1978). Instructors in science or quantitative courses commonly require students to solve many problems for homework and may even demonstrate solutions in class on the board. It is less common for college instructors, including graduate student assistants leading problem-solving sessions, to break down the process through verbal or written annotation methods (Leonard, Dufresne, & Mestre, 1996).

Instructors may also fail to realize when the teaching goals they articulate do not match the teaching approach they routinely use. This lack of coherence arises when the teaching theories that instructors profess are not the theories guiding their actual practice (Argyris, Putnam, & McLain Smith, 1985). For example, most instructors wish to promote student learning. Specifically, many aim to help undergraduates develop as *deep learners* (Biggs, 1987; Entwistle & Ramsden, 1983): learning for understanding and developing the capacity for independent learning. Instructors who seek to help students not only acquire content but also a

deeper understanding of disciplinary ways of knowing must be explicit about the cognitive processes embedded in academic work. We have found that in practice, however, students and teachers alike frequently focus on the specificity of the content to be learned, even though their espoused goals for student learning are those recognized as higher-order thinking skills: analysis, synthesis, evaluation (Bloom, 1956), and creation of knowledge. Often the ideas about teaching that instructors use in everyday practice are a form of *tacit knowledge*—understandings shaped by experience, beliefs, and context that they often cannot explain (Argyris & Schön, 1974; Polanyi, 1966). Before any change in practice is possible, instructors must recognize the implicit theories they are using in practice and willfully examine them to bring them into coherence with their explicit goals of teaching.

Graduate student teachers face these dual challenges. They are likely to assume that the learning processes and academic skills needed for learning in the discipline are obvious. In addition, their theories-in-action may not match their professed theories of teaching. The invisibility of the expert's learning processes contributes to this lack of coherence between professor goals and teaching practices. As we set about to train experienced graduate student instructors to lead the academic skills workshops, we uncovered unexpected resistance and difficulties. As part of our training process, then, we had to find ways to make their assumptions about learning and teaching explicit. Only then could they effectively examine and reassess their teaching beliefs.

Descriptions of the Programs and the Methodology

The seven graduate student facilitators we write about here all participated in our program for either one or two semesters, each offering two to eight academic skills workshops during that time. We found that our facilitators' experience and reflections constituted a rich case study that could provide insight into qualitative questions about what occurred in our program, the implications of those occurrences for the individuals involved, and the relationships linking those occurrences (Honigmann, 1982). These kinds of characteristics describe what may be called a "found" research study.

In retrospect, we identify ours as a purposive and unique sample (Merriam, 1998); we only recruited and hired graduate students who were recommended as good teachers and whom we found, in interviews, to be reflective about their teaching. Our sample was also unique in that each facilitator was attracted to teach in the program, expressing an interest in teaching about process, as much as content. As teaching and learning center professionals, we conducted the training for our sample of graduate student teachers. We also conducted the interviews. Thus, the interviewed graduate student facilitators were being asked to share their beliefs and assumptions with their own teaching mentors, knowing fully our assumptions about the importance of teaching learning processes.

Each facilitator provided workshops for a specific class in his discipline. We wanted the workshops to be designed with the research on novice versus expert problem solvers in mind. This research shows that in addition to disciplinary knowledge, effective problem solving requires a knowledge of strategies, the ability to use what one knows, and effective beliefs about the process of problem solving. Novice problem solvers, such as college students, typically rush to computation, believing that the process is quick and as simple as finding an equation that fits the problem. Expert problem solvers, on the other hand, explore, adapt, and reject various paths as part of thinking through the process (Schoenfeld, 1985). We thus trained workshop facilitators to guide students into thinking consciously about problem-solving processes. For example, a workshop—Problem Solving for Physics 101—taught students to begin their problem-solving process with techniques for fully comprehending a given physics problem: restating a problem in their own words, writing down all givens and constraints, and drawing and labeling a picture that represented the problem visually.

As is often the case when developing new programs, we began the process of training these graduate students with one kind of plan, but as we assessed the effectiveness of our training process, we made changes to the approach we took. In the pilot semester of the program, each of our three graduate facilitators had an initial meeting with a staff member of our center to discuss students' learning challenges, their own learning and problem-solving

processes, and the aims of the program they would lead. Either before or after this meeting, facilitators were given a problem-solving strategies tip-sheet to study (see Appendix A), as well as a model lesson plan to work from. They were instructed to draft their own workshop lesson plan, including opportunities for students to practice the strategies to be taught. After attempting to draft a plan, each facilitator again met with a staff member for feedback. Their plans were essentially review sessions, focused on solving a specific problem rather than on teaching a problem-solving process.

Recognizing the graduate students' difficulty in understanding and isolating their processes, we attempted one-on-one training conversations with the three facilitators from our pilot cohort. This conversation worked well in the one case where we paired an economics graduate student, "Mary," with one of our staff who was a chemist. It was not as successful when the graduate facilitators had follow-up conversations with a staff member who was a humanist by training or with the center's senior graduate fellow, who was a molecular biologist and peer.

Having learned from our experience with the pilot cohort, we designed a different approach for the other four facilitators who led sessions during the second and third semesters of the program. They met instead with their cohort to discuss their processes and to "workshop" lesson plans together. This method was more successful in clarifying beliefs and promoting change. We held a total of three such meetings throughout the academic year. As they compared their processes, these four facilitators were able to isolate the specific, transferable skills and strategies, while articulating some differences as well. They also read each others' lesson plans, getting and giving ideas for building in opportunities for interaction and practice.

We interviewed five graduate students who participated in the program for one year and collected their thoughts and actions as evidence of changes in their teaching beliefs. Four were from the second cohort, but one facilitator from the pilot cohort (Mary) was interviewed for the study. Though we engaged in a long-term observation, talking with members of our sample over the course of a year, we report here on responses to a formal interview occurring on one occasion, at the end of the year of service. Each

interviewee was asked the same questions, though not always in the same order. Three of the interviews were conducted like a focus group, with members of the group answering the questions and discussing their answers with each other. Two of the interviews were conducted with the interviewer alone. Each interviewee's comments were written down as well as videotaped, allowing for confirmation of what was heard. We also enhanced internal validity through "member checks," giving each interviewee the opportunity to review the data we had collected and our interpretations of those data (Merriam, 1998). Finally, to triangulate our findings, one or both of us observed each facilitator teaching the workshop in question on at least one occasion. These observations indicated that some of the professed teaching beliefs were reflected in teaching practice. Our aim here is not validity, however, but what Wolcott (1994) calls understanding: "something else, a quality that points more to identifying critical elements and wringing plausible interpretations from them" (p. 366).

As we summarize the findings in the next section, we note the contrast between the graduate students who met together to discuss plans and two facilitators from the pilot cohort who never came to understand our conception of learning processes. We speculate on the role that the group conversations might have played in the development of these graduate students as teachers. Here we outline five of the promising differences in teaching beliefs effected by this program.

Observed Attitude Changes

We noted some changes in facilitators' attitudes as the result of having gone through the program. We found that facilitators

1. Became more aware of the processes they use to learn their disciplines
2. Revised their perspectives on novice learners
3. Examined their beliefs about students as recipients and constructors of knowledge
4. Recognized the need for instructors to teach learning processes
5. Experienced the value of a "teaching commons"

1. *Facilitators became more aware of the processes they use to learn their disciplines.* When they were first asked to lead these sessions focusing on process rather than content, several of the graduate student facilitators were unsure about what we were asking of them. They did not think of their processes as the core of how and what they learned in their disciplines. What did it mean to teach physics problem-solving strategies rather than a specific physics problem? What were the actual steps they took or the questions they asked themselves? We found that almost all of our facilitators used their processes intuitively and unconsciously and needed some time to reflect before they could articulate them. Some facilitators found it more challenging than others.

Though Mary (economics), "Vince" (physics), and "Amy" (chemistry) each had a tip-sheet outlining some problem-solving steps for students and instructions to teach those, their first draft workshop plans were for review sessions in which students were led through solutions to particular problems. Per our suggestion, the facilitators had included interactive segments, but they were discussions of particular steps in the problem or particular concepts involved, not discussions or activities designed to help them understand or practice their processes. (For instance, they might have included a segment in which students were asked to draw a picture of the problem, then compare their representations with peers in the room.) We speculate that our graduate student facilitators were wrestling with their prior knowledge of teaching, and it was difficult for them to imagine a teaching task so different from the models they had been exposed to as students themselves. We also believe that we were confronting powerful prior conceptualizations about learning. Our disciplinary experts were more aware of their disciplinary knowledge than of their disciplinary habits of mind. They thus reverted to a content-transmission model of teaching, which is commonly modeled in quantitative disciplines. Conversations with a center staff member who was a chemist, and more study of the tip-sheet, led to greater understanding for Mary. As we noted earlier, however, neither Vince nor Amy ever came to our understanding of the goals of the workshops.

The other facilitators more quickly understood the teaching goal, but they had not reflected on their own learning process

and would have been hard-pressed to describe them before this experience. As “Nick” (engineering) expressed it, “I hadn’t thought about problem solving in an abstract way.” Once he did think about it, however, he quickly realized the system behind what he had been doing “unsystematically.” He was able to write out a list of techniques and “put them in order.” Since teaching the workshop and after discussing it with the course head for an introductory physics class, he realized other aspects of his process, which he added to the workshop program.

Similarly, “Lachelle” (molecular biology) revealed that before the workshops, “[she] had not thought of biology as a problem-solving field.” On reflection, she realized that these content-heavy courses also required application of that content through problem solving. It turned out that this skill was essential to learning in the discipline, but the teaching conventions so emphasized content coverage that she had failed to see how necessary problem-solving skills were to success. Nor had she recognized the sophistication of her own processes.

Perhaps the most interesting development was with “Susan” (engineering), who led calculus workshops and was inspired to better understand her own process once asked to teach it. She started by studying the tip-sheet and found that even though she did take many of the steps outlined, her process was not quite captured. She reported having so “internalized [her] process” that she had to view herself with a different question in mind. Instead of trying to get the answer, she wanted to study *how* she got the answer. She set to work on some unfamiliar problems, monitoring her own processes as she went. She realized that she questioned herself at every step of the way: “I was like my own teacher, asking myself questions that tested my ideas or clarified my understanding.”

She was so interested in what she was discovering about her own processes that she decided to read further about others’ problem-solving processes, discovering Polya’s 1957 book *How to Solve It*. Combining her own self-reflexive process with some “phases of problem solving” described by Polya, Susan created her own tip-sheet for the Center called “Questions to Ask Yourself When Problem Solving” (Appendix B). It broke down the process into four phases, each with an attendant set of questions. For

example, “Phase I: Understanding the Problem” included such questions as, What information have I been given and what information do I need to find? Can I draw a picture depicting the given information? Have I seen a similar problem before?

All of the facilitators affirmed that becoming more aware of their own processes was necessary for teaching strategies to students. As Nick put it, “When you teach it, you have to learn it, and you have to know it.” The facilitators’ heightened awareness of their own academic processes is consistent with the academic benefits accrued by leaders of supplemental instructions sessions (Stone, Jacobs, & Hayes, 2006).

2. *Facilitators revised their perspectives on novice learners.* The expert who teaches is challenged to recognize what is obvious versus what is familiar (Leamnsen, 1999). We have found that novice teachers are more likely to conflate the two, mistakenly thinking that students are as familiar as they are with certain disciplinary habits and ways of thinking. As Mary (economics) became more certain of the workshop’s aims and the focus on process, she decided she was unsure about the value. Did not students already do these things—such as drawing graphs and considering the concepts involved—intuitively, as she did? Would they be insulted by such instruction? Could we not avoid that by just inviting the students who were doing poorly to attend?

Mary’s conception of the obvious, as opposed to the familiar, was not atypical of her cohort. Vince, for instance, did not articulate these concerns verbally, but they were manifest in his actual leading of the physics problem-solving workshop. Despite a carefully designed lesson, he abandoned the plan as soon as he began the session, reverting to his “review session” approach. One telling detail was that Vince did not bring a copy of the problem to the workshop as planned, electing instead to read it aloud to the students and then start solving on the board. Center staff intervened to make copies and otherwise maintain the emphasis on the process. In a post-session debrief, Vince seemed surprised by our assessment that it had not gone as planned. When asked why he did not bring copies of the problem as planned, he said that students could do some of the steps, such as restating the problem in their own words, “in their heads.” He also thought these things

were “easy” and “could be done relatively quickly,” as this was his own experience.

For most of the facilitators, leading academic skills workshops and getting some student feedback shifted these misconceptions. For instance, about a week after an economics problem-solving workshop, the center solicited candid feedback from workshop participants, and Mary was surprised by the overwhelmingly positive responses:

This workshop helped me clarify my thought process when solving Econ problems. Also, it was good being told how important thinking is when solving a problem. They gave us some steps to follow when doing the problem and made sure to remind us to think intuitively. That gave me more confidence when tackling the problem sets and has resulted in my getting very high scores on the problem sets without too much stress.

Other students' comments included, “I think I'll approach my problems with the ‘is that reasonable?’ conjecture,” and, “It was also helpful when you discussed the need to separate the givens from the constraints.” Things that Mary thought basic were new and worth learning for a novice. Mary tried to understand the feedback by imagining herself in the situation of the novice. She realized that she was herself “more deliberate in this way when the problem is very unfamiliar or elusive.” She recognized that for novice students, *most* problems are unfamiliar or elusive.

Lachelle (molecular biology) claimed that her newfound understanding of the novice student had been profound: “It is easy to lose track of what it is like at that stage. It has been a long time since I approached problem solving as a novice.” Working with students on these workshops was “an eye opener.” She had expectations about what students knew and how they conceptualized “what it means to be a student.” For instance, reflecting on her teaching of a writing seminar about science, she realized students had different definitions of “reading.” What a student might call “reading a text” would be merely “glancing over a text” to this graduate student teacher. As she reflected on teaching both the writing seminar and the academic skills workshop for molecular biology, she mused that “we get disconnected from

what it means to be an introductory student” and speculated that this gap widens with increasing expertise, specialization, and years away from the novice learner experience. Susan similarly argued that the most experienced professors may be the most challenged to see the novice’s point of view.

Susan was equally surprised at how “different my study process was from others’ processes.” For one, she “never memorized anything.” Her process was much more about understanding a theorem by engaging it in some way, preferably by drawing a picture, which led to remembering it for far longer. In addition, she was truly puzzled by the fact that the undergraduates initially found this to be a “strange suggestion.” She came to realize that they were treating problem solving as “a recipe,” trying to memorize the steps needed to solve *this* problem. They spent less time actually trying to learn the theorem and were more likely to see each problem as unique. She never knew there was such a big division between her processes and theirs. As she put it, “the surprise went both ways.” She was surprised by what students did not know, and the students were surprised by what the problem-solving process demanded of them.

The most experienced teacher in the group was not surprised. Allie (economics), a former high school teacher, was prepared to find a lot of variety in students’ skill levels and expected many students to be unfamiliar with aspects of her discipline. She expected them to need this instruction. By facilitating these academic skills workshops, the other teachers were able to make up, at least in part, for their lack of experience and began to acquire Allie’s more seasoned perspective—one more likely to recognize the students’ level and the difference between the obvious and the familiar.

3. *Facilitators examined their beliefs about students as recipients and constructors of knowledge.* For many facilitators, recognizing the value of teaching process as well as content led to a reevaluation of traditional modes of instruction. Some articulated a relationship between overvaluing content and the pedagogical strategy of transmitting content to students, predicated on the assumption that the mind is a receptacle for information. After the workshops, the facilitators were more likely to think of students as

needing instruction and practice if they are to be coconstructors of knowledge and, thus, learn deeply.

Lachelle said that without this experience it would have “taken [her] a couple of semesters” to realize what some of the learning challenges were for students. Introductory biology is a “content-driven class,” but leading these workshops led her to see the discipline anew. For one, she noted that we often ask students to memorize information, then “give it back,” and then “apply it” to solve a problem. If this exercise is what we are going to ask students to do to demonstrate that they have learned the material, then they need some practice doing it. She believed that it is important to highlight processes if the goal is to help students learn to think like scientists rather than to regurgitate information. One way to emphasize process is by solving problems in class. As she put it, “More chalk equals more process.” She wants to get students actually watching the process or participating in it. She found it hard to imagine how to do this, given “inherited models” of content transmission in a lecture based on slides: “That’s how I was taught, and probably how my professors were taught.” She said that this experience has given her some ideas about making students constructors of knowledge, rather than recipients.

Lachelle was already thinking about the content-driven nature of the introductory class in her discipline, and this reflection led her to the “less is more” determination. She decided that in trying to cover too much material, she lost opportunities for deeper learning. She had not realized before that what was missing was not just time to linger on a topic but a *way of engaging* the topic. She told a story about encountering what seemed to be new material in graduate school. “I was certain I had never seen this stuff before.” Upon reviewing old class notes, however, she recognized that she had, in fact, studied and learned some of these things. She earned an “A,” but the material just did not stick. She knew one problem was the rush to coverage, but part of the explanation for her memory loss was that she “was not taught a process.” She learned the material in a particular way, and she had to learn it again, in a more engaged way, to build on it for her future as a molecular biologist. She said that, as a teacher, she wants to promote those more engaged processes.

Susan (engineering) talked about the difference between grappling with a concept versus grappling with a problem-solving process. She gave an example from her work as a teaching assistant: "A student comes to my office confused about a concept, so I ask questions, trying to guide them to understand the thing that is in the way. But I never thought about needing to teach them how to do this on their own, how to ask their own questions." Now she is concerned that, without the proper instruction, many students are "not equipped to study on their own." In this case, part of her job as a teacher is to teach them how to study and thus construct their own knowledge.

Allie (economics) defined "the magic of the classroom" as a space for the active construction of knowledge. She stated her intention to create a space where "we are here in a room figuring something out together." As the most experienced teacher, this experience only solidified previous conceptions. Deep learning requires active engagement and the discussion of problem solving as a process, and this engagement is the antithesis, she said, of teaching with PowerPoint. She argued, "PowerPoint kills class participation." By simply transmitting knowledge, instructors allow students to miss out on the experience of solving a problem and thinking it through together.

4. *Facilitators recognized the need for instructors to teach learning processes.* As they have critiqued traditional lecture or "chalk and talk" pedagogy, they have also considered how these ideas might affect their future teaching. What would it look like to teach problem-solving processes in an introductory math, economics, or physics class? Would one offer a full class period focused entirely on the process, similar to the center's workshop? Or could the processes be tied to the content and incorporated throughout the course? The facilitators uniformly agreed that the instruction of process should not be relegated entirely to an external unit, such as a teaching and learning center. It was the instructor's responsibility.

Lachelle imagined that a workshop on problem solving could be "the first precept or discussion section" of the year. At this point, students are less focused on the grade and more likely to be open to strategies for learning. She also maintained that teachers should be explicit about the fact that the strategies are

transferable to other disciplines. She noted that she was teaching a writing class—obviously about process versus content—and yet students had a hard time seeing writing as a transferable skill. They wondered how they will now learn to write “an economics paper” or a “literature paper.” Lachelle recognized how difficult they found it to think about writing as similar across the disciplines, as the task of constructing and supporting an argument. Given her experience teaching writing, she came to believe that students may need direct instruction to recognize problem-solving strategies learned in molecular biology as transferable to other disciplines such as math and physics.

What might a course look like if such instruction were incorporated throughout the semester rather than relegated to a session? Nick (engineering) imagined incorporating problem-solving instruction throughout the term, wedding it to the content: “Since there are problems with diving into problem solving before any content has been covered, I would probably try to distribute the techniques or break the lecture into five-minute “mini lectures” to be given through the term—perhaps a short discourse on a technique followed by desk or pair work on a problem which illustrates its utility, handed in after the first five minutes of lecture. It would also be an easy way of taking attendance!”

Allie (economics) agreed with this approach philosophically, arguing that by engaging in the process of doing economics, students would learn that these questions and strategies are part of working in the discipline. Problem solving would not be a separate class to be taught. She imagined having students work on problems, then present to the class what they did. Each group would be pressed to answer such questions as these: How did you approach this? How was it like what you did before? Her experience with the center made her consider exactly how she would teach the processes, but it was not the key factor in her beliefs. She knew the importance of focusing the class on process from her own experience as a learner and from her previous experience teaching K–12, even if she did not articulate this idea aloud.

Allie also felt strongly that process instruction would be more effective if done by the course instructor rather than by the kind of supplemental program that the Center for Teaching and Learning designed. For one, the course instructor knows students’ needs,

whereas “by design, the workshop facilitator can’t know the students.” Susan also talked about the need for the course instructor to accept this responsibility. Now that she knew that even highly prepared and successful students do not have the strategies, she argued “it would be irresponsible” for a course instructor not to teach these processes.

Susan recounted her taking a class as a college student where the problem-solving process was taught explicitly. It was an excellent course for her and the kind she intends to run as a faculty member. She criticized the model in which the professor works the problem and delivers a totally clean package with “no wrong turns.” Susan argued that this model does not represent the nature of learning in the field and that we should ask more of our own problem-solving questions aloud and “show the messy process.” In other words, teachers should allow for the fact that before they use an equation, they face uncertainty. Students should see what experts do to take things apart. In Susan’s view, instructors should first articulate their own questions about a problem out loud, then have students add their own questions and thought, and finally have them work on the problems in class, with the instructor’s guidance.

Lachelle used an opportunity to get students practicing an academic skill in a writing seminar she was teaching on science and media. “[She] was always sold on the idea [of study skills instruction] for students,” but then she saw how it affected her own teaching. As the writing seminar progressed, she realized that her definition and expectation of “reading” in the discipline were different from those of her students. To make her processes and expectations transparent, she handed out a tip-sheet on active reading skills and devoted ten minutes of class time to actively reading an article. Students practiced posing questions and writing notes in the margins. This activity led to the most engaging and thoughtful discussion of a text for the semester. She speculated that her students were more likely to recall and use this reading process than if she had simply passed out the tip-sheet and suggested they try some of these strategies at home.

5. *Facilitators experienced the value of a “teaching commons.”* All who had the opportunity to meet and talk with the facilitator cohort found it valuable. For one, they solidified their understanding of

their own processes by talking with others using similar cognitive strategies to tackle different disciplinary questions and problems. They also felt that they were able to develop better workshop lesson plans by reading each others' plan drafts and discussing the benefits of particular approaches and workshop activities. Finally, with a supportive, thoughtful sounding board, they could discuss a broad range of pedagogical issues: new teaching goals, new ways of teaching, and the challenges encountered in teaching.

Lachelle found it easier to see her own discipline of molecular biology as a "problem-solving discipline" once she compared notes and recognized similarities with her fellow teachers in more obvious problem-solving disciplines such as math and physics. She came to deeper understanding of her own process but also more conviction about the value of learning this process, given the transferability to other disciplines. She said it would be easier to sell to students and that teachers should be direct about how the skills can be used in other contexts, thus eliciting more student motivation to learn them. Lachelle also argued that when considering or trying out a new teaching model, instructors "need a quorum" and some "support" from others.

She talked about fellow teachers as tremendous resources for understanding and addressing "student roadblocks." These difficulties are "roadblocks that they [students] have in common" and other teachers are likely to have encountered them. She imagined turning to more experienced teachers in the future, learning what they have observed from teaching the same course over time and thus getting some advice about "what to anticipate." Lachelle also imagined the benefits of novice and experienced teachers discussing roadblocks together, coming up with potential solutions, experimenting with them, and sharing appropriate strategies and methods.

Conclusion

Before leading these workshops, the graduate students all had the explicit goal of promoting their students' learning of content. Each of them believed that students showed their understanding

of content through their ability to solve problems, but their teaching-in-action illustrated their tacit belief that the processes required for students to solve problems—a higher-order skill—were obvious. Their own problem-solving approaches were invisible to them, thus supporting this belief. Most of the graduate students were challenged to recognize the need to teach processes of thinking in the discipline in order to encourage deep learning. The graduate students who worked with their peers as they developed these workshops confronted these inconsistencies between their goals for teaching and their teaching practice. They also showed greater willingness to try other teaching approaches that made the processes of problem solving more explicit.

As they imagine designing and teaching their own courses, most of the graduate student facilitators say that they will incorporate academic skills instruction into class time or that they see the value in it, even if they are not sure how, exactly, to implement it. They agree that students cannot pick up this kind of learning in a one-time workshop. The facilitators also address the formidable goal of teaching transferable skills. As the molecular biologist put it: “Transfer is the challenge. I’m still struggling with how to teach them ‘the skill’ and how to use it, and recognize the need for it, in another context.”

This comment brings us to the hopes we have for these future faculty and their own transfer of knowledge and skills. In addition to bringing academic skills instruction to their future classes, we also hope they will recall the value of talking about teaching with a group of fellow instructors. Perhaps their experience in this program will encourage them to extend their involvement to participating in teaching and learning center programming, joining face-to-face and online pedagogy discussion groups, or starting their own formal or informal networks with fellow faculty. Such activities constitute a kind of “teaching commons”—opportunities for an exchange of ideas among a “community of educators committed to pedagogical inquiry and innovation” (Huber & Hutchings, 2005, p. x). These kinds of meetings provide faculty with support and resources that will better enable them to meet the challenges of teaching for deep learning and transfer.

Appendix A

Successful Strategies for Solving Problems on Assignments

Solving complex problems is a challenging task and warrants ongoing effort throughout your career. A number of approaches that expert problem solvers find useful are summarized next, and you may find these strategies helpful in your own work. Any quantitative problem, whether in economics, science, or engineering, requires a two-step approach: analyze, then compute. Jumping directly to “number-crunching” without thinking through the logic of the problem is counterproductive. Conversely, analyzing a problem and then computing carelessly will not result in the right answer either. So, think first, calculate, and always check your results. And remember, attitude matters. Approach solving a problem as something that you know you can do, rather than something you think that you can’t do. Very few of us can see the answer to a problem without working through various approaches first.

Analysis Stage

- Read the problem carefully at least twice, aloud if possible, then **restate the problem in your own words**.
- **Write down all the information** that you know in the problem and separate, if necessary, the “givens” from the “constraints.”
- **Think about what can be done with the information that is given.** What are some relationships within the information given? What does this particular problem have in common conceptually with course material or other questions that you have solved?

- **Draw pictures or graphs** to help you sort through what's really going on in the problem. These will help you recall related course material that will help you solve the problem. However, be sure to check that the assumptions underlying the picture or graph you have drawn are the same as the assumptions made in the problem. If they are not, you will need to take this into consideration when setting up your approach.

Computing Stage

- If the actual numbers involved in the problem are too large, small, or abstract and seem to be getting in the way of your thinking, **substitute simple numbers and plan your approach**. Then, once you get an understanding of the concepts in the problem, you can go back to the numbers given.
- **Once you have a plan, do the necessary calculations.** If you think of a simpler or more elegant approach, you can try it afterwards and use it as a check of your logic. Be careful about changing your approach in the middle of a problem. You can inadvertently include some incorrect or inapplicable assumptions from the prior plan.
- Throughout the computing stage, pause periodically to **be sure that you understand the intuition behind each concept in the problem**. Doing this will not only strengthen your understanding of the material, but it will also help you in solving other problems that also focus on those concepts.
- **Resist the temptation to consult the answer key** before you have finished the problem. Problems often look logical when someone else does them; that recognition does not require the same knowledge as solving the problem yourself. Likewise, when soliciting help from the AI or course head, ask for direction or a helpful tip only—avoid having them work the problem for you. This approach will help ensure that you really understand the problem—an essential prerequisite for successfully solving problems on exams and quizzes where no outside help is available.
- **Check your results.** Does the answer make sense given the information you have and the concepts involved? Does the answer make sense in the real world? Are the units reasonable?

Are the units the ones specified in the problem? If you substitute your answer for the unknown in the problem, does it fit the criteria given? Does your answer fit within the range of an estimate that you made prior to calculating the result? One especially effective way to check your results is to work with a study partner or group. Discussing various options for a problem can help you uncover both computational errors and errors in your thinking about the problem. Before doing this, of course, make sure that working with someone else is acceptable to your course instructor.

- **Ask yourself why this question is important.** Lectures, precepts, problem sets, and exams are all intended to increase your knowledge of the subject. Thinking about the connection between a problem and the rest of the course material will strengthen your overall understanding.

If you get stuck, take a break. Research has shown that the brain works very productively on problems while we sleep—so plan your problem-solving sessions in such a way that you do a “first pass.” Then, get a night’s rest, return to the problem set the next day, and think about approaching the problem in an entirely different way.

Source: Adapted in part from Walter Pauk. *How to Study in College*, 7th ed., Houghton Mifflin, 2001.

Appendix B

Questions to Ask Yourself When Problem Solving

Phase I: Understanding the Problem

What information have I been given? What information do I need to find? Can I draw a picture depicting the given information? How would I restate the problem in my own words? What type of problem is this? Have I seen a similar problem before? Is there a similar problem in the textbook? What characteristics of the given information jump out as potentially important? Why might they be important? Do I fully understand the set-up and what is required of me? If not, what can I do that would help me better understand this?

Do not move on to Phase II until you feel sure you understand the problem!

Phase II: Devising a Plan

- **Initial ideas:** Do I have any initial ideas as to how I might possibly solve this problem? What other information can I derive from the given information? How have I solved a similar problem in the past?
- **Following up on initial ideas:** Where would this idea get me? How would it help me get closer to the answer? What would I do next after this idea? Does the idea make sense?
- **Troubleshooting:** Can I think of a simpler version of this problem that is easier to solve? How would I solve the simpler

problem? Can I break this problem into smaller parts that are easier to solve? Have I considered *all* pieces of given information? What other ways might I approach this problem?

Phase III: Carrying Out the Plan

- **Have I achieved what I intended to in this step?** Is the result of this step correct?

Phase IV: Checking Your Answer

- **Verifying your answer:** Does my answer make sense? Is it plausible? Can I substitute my answer for the unknown in the problem? Does my answer match up with the given information? Does my answer have the right units?
- **Learning from your solution:** Can I look back and see a simpler way to solve this problem? Can I succinctly summarize the approach I used to solve this problem?
- **Why was I asked this to solve this problem?**

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