CHAPTER TWO

RESEARCH: EVIDENCE THAT LEARNER-CENTERED APPROACHES WORK

Considerable research justifying the effectiveness of learner-centered approaches exists. A significant amount has been published since the first edition of this book. In fact, the growing body of evidence supporting the effectiveness of these approaches was what finally convinced me of the merits of a second edition. This chapter will summarize a sampling of that work, updating what was highlighted in the first edition and introducing new findings.

I can imagine a number of faculty reading that opener and thinking that this might be a chapter to skip. Most faculty don’t enjoy reading research unless it’s in their area of scholarship or on a topic of intense interest. With research on teaching and learning, whether it’s done in the field of education or by practitioners in the disciplines, there’s another reason it isn’t read. Many faculty don’t think it’s very good and don’t think there’s much to be learned that might benefit what they do in the classroom.

The neglect of research on teaching and learning is understandable to some degree. Educational research, like research in all our fields, is not uniformly good. The research methodologies, always presented in excruciating detail and with lots of jargon, are frequently unfamiliar. The implications of findings are not routinely spelled out. This research, again like much done in our disciplines, better informs subsequent research than practice. But I don’t think that justifies the neglect of research on teaching and learning.
Here are just some of the benefits that come from knowing something about research relevant to learner-centered teaching. If you aren’t using any learner-centered strategies, the research findings may offer evidence that convinces you to try some of these approaches. If you are using some of them, understanding more about the design features that make them work and the learning outcomes they most often affect can increase the effectiveness with which you use them. If you believe in learner-centered teaching and want to advocate for these approaches, even just informally recommend them to a colleague, your advocacy will be more effective if you know something about how they’ve been tested and the kind of evidence that supports how well they work.

Two final benefits are more broadly applicable but still relevant to learner-centered teaching. Because research on teaching and learning remains so little known, much instructional practice is not evidence-based. That seems very ironic in an academic culture where evidence is revered. Teaching is devalued and learning is compromised when practice is not guided by what is known about making both effective. Knowledge of the research can motivate the kind of changes that will make instruction more evidence-based. And finally, reading educational research relevant to learner-centered approaches just might convince you that there’s other research on teaching and learning worth your time. Beyond these benefits, my goal for this chapter is to present an interesting, succinct, nontechnical summary of research—one that will keep you awake and intrigued.

The chapter does not contain a comprehensive review of the literature on learner-centered approaches. I don’t have enough time left in my career to put together that kind of review. The research justifying these approaches has been done in all sorts of different fields, starting with education and its various subfields and ending with practitioner pedagogical research now being done in virtually every discipline. Finding everything—or just finding most things—is a daunting task. I’m pretty certain I read more on this topic than most folks, and I’m constantly finding things I haven’t read and should have known about.

In addition to the research being located in many different places, there are all sorts of different techniques, strategies, and
approaches that fall under the learner-centered umbrella. I will write more subsequently about how this definitional looseness makes it difficult to determine whether something is or is not learner-centered. At this juncture, it’s a question of what to include in the review when we are confronted with such a wide array of options. I’ve opted for important, high-quality, interesting work—actually, I find much of what I’m going to write in this chapter fascinating, but then one must be careful of hyperbole in academic books.

Reviews of research often integrate findings using quantitative methods like meta-analyses, but the diversity of research relevant to learner-centered approaches rules out any sort of quantitative analyses. Too many different research methodologies have been used. The goal of most research reviews is to integrate what is known as a way of making clear what is not known and thereby helping to direct the research agenda. That’s not what practitioners need to know about the research on learner-centered approaches. They need to understand the kind of questions that have been addressed by the research, what answers have been found—which, for educational research, with its lack of definitive conclusions, always means the answer supported by the weight of the evidence—and, most important, what they should be doing about the results. Those are the questions that should be answerable by the end of the chapter.

**Research Updates**

The 2002 edition highlights research done in three areas that merit updating: deep and surface learning, faculty orientations to teaching, and self-regulated learning. The research in each of these areas has been conducted in education and fields related to it. It is not research on learner-centered approaches per se, but focuses on the principles that learner-centered approaches exemplify.

**Deep and Surface Learning**

This work, reasonably well known among faculty (though for most the knowledge doesn’t extend much past the difference between the two approaches to learning), was launched with a particularly
seminal study by Marton and Saljo (1976; updated and analyzed in Marton, Hounsell, and Entwistle, 1997). They had students read material from an academic text and then asked them to describe what they had been reading. Ramsden (1988, p. 18), another important scholar working in this area, has succinctly summarized those first findings: "They found evidence of qualitative differences in the outcome of students' reading. The differences were not about how much the students could remember, but about the meaning the author had tried to convey. Some students fully understood the argument being advanced and could relate it to the evidence being used to support it; others partly understood the author's message; others could only mention some of the remembered details."

When students concentrated on memorizing the facts, focused on the discrete elements of the reading, failed to differentiate between evidence and information, were unreflective and saw the task as an external imposition, Marton and Saljo characterized their approach as "surface" learning. When students focused on what the author meant, related new information to what they already knew and had experienced, worked to organize and structure the content, and saw the reading as an important source of learning, Marton and Saljo characterized the approach as "deep." Ramsden (1988, p. 23) further outlines the differences between the two approaches. For students using surface approaches, "texts were a flat landscape of facts to be remembered, rather than an area dotted with salient features representing principles or arguments around which stretched plains of evidence."

Ramsden (1988, p. 271) also sees connections between deep learning and transformative learning: "Learning should be seen as a qualitative change in a person's way of seeing, experiencing, understanding, conceptualizing something in the real world—rather than as a quantitative change in the amount of knowledge someone possesses." Deep learning is what helps students achieve education's broadest and most important goals. "Higher education should... be concentrating on helping students develop skills, attitudes, knowledge, and understanding that will be of maximum value beyond academic; not just an induction into the world of work in a specific profession, but also an effective preparation for life in the 21st century" (Entwistle, 2010, p. 20).
“Since the original naturalistic experiment, the distinction between deep and surface approaches has been widely confirmed across most subject areas,” according to Entwistle (2010, p. 24). That confirmation comes from instruments (Biggs, Kember, and Leung, 2001; or Tait, Entwistle, and McCune, 1998, reprinted in Entwistle, 2010, pp. 55–54) that reliably indicate whether students are using deep or surface approaches. Teachers can use these instruments to give students feedback and encourage them to explore the more productive approaches of deep learning.

The research on deep and surface learning has resonated with faculty. Most see all too many students focused on memorizing material without much, if any, understanding of what they are memorizing. Surface learning approaches result in material being retained briefly, and most faculty have seen that firsthand as well. The question, then, is whether learner-centered approaches promote deep learning. And the most convincing evidence that they do is found in research on faculty orientations to teaching.

**Faculty Orientations to Teaching**

As early as 1988 (Greerson), research was showing that there was a relationship between teacher-centered or student-centered approaches and the type of learning experiences that students reported. In that study, student-centered instructional approaches were preferable across a number of different variables. Those early results have been confirmed consistently, starting with Kember and Gow’s (1994) study of teachers and students within departments. Their results “suggest that the methods of teaching adopted, the learning tasks set, the assessment demands made, and the workload specified are strongly influenced by orientation to teaching. In departments where the knowledge transmission orientation predominates, the curriculum design and teaching methods are more likely to have undesirable influences on the learning approaches of students. Departments with a greater propensity toward learning facilitation are more likely to design courses and establish a learning environment that encourages meaningful learning” (p. 69).

In the late 1990s, Trigwell and Prosser with various colleagues developed an Approaches to Teaching Inventory (revised
in Prosser and Trigwell, 2006), which identifies the extent to which a teacher is oriented to information transmission and teacher-focused, or oriented to conceptual change and student-focused—in the parlance of this book, whether the instructor is teacher-centered or learner-centered. In 2010, Trigwell reported on five research studies that administered this instrument to faculty at the same time their students completed an approaches-to-learning instrument (such as Biggs, Kember, and Leung, 2001) and then compared the results. Several of these studies were impressively large: one involved 46 college science teachers in 48 classes with 3,956 students (Trigwell, Prosser, and Waterhouse, 1999); another involved 55 large first-year courses, taught by multiple teachers across a range of disciplines, generating data from 408 teachers and 8,829 students (Trigwell, Prosser, Ramsden, and Martin, 1999).

About the results from all these studies, Trigwell (2010) writes, “Together these studies indicate, with classes as the unit of analysis, that an information transmission/teacher-focused approach to teaching is strongly and positively associated with surface and non-deep approaches to learning, and that a conceptual change/student-focused approach to teaching is positively associated with deep and non-surface approaches to learning” (p. 121). Trigwell offers a description of the student-focused orientation that confirms it is what this book refers to as learner-centered teaching: “When teachers report that they have the student as the focus of their activities, where it matters more to them what the student is doing and learning than what the teacher is covering, when the teacher is the one who encourages self-directed learning, ... where the teacher provokes debate, uses a lot of time to question students’ ideas and to develop a ‘conversation’ with students in lecture, then his or her students are less likely to adopt a surface approach and more likely to adopt a deep approach” (p. 121).

This research offers a convincing commendation of learner-centered approaches. When they are used, the claim can be justifiably made that they promote a different, deeper, and better kind of learning. It is a kind of learning that lasts, and learning that enables higher education to achieve some of its broadest and highest goals.
INDEPENDENT, SELF-DIRECTED, AND SELF-REGULATED LEARNERS

Early in my faculty development career, I encountered the idea of autonomous learning in the work of Boud (1981), whose edited anthology describes how education typically makes students very dependent learners. They depend on the teacher to identify what needs to be learned, to prescribe the learning methods, and finally to assess what and how well they have learned. Many arrive in our classrooms needing teachers to tell them virtually everything—how many words their paper should contain, what font they should use, how many references it must include, and how wide they should make the margins. If these details are not specified, students will ask and be upset if they must make these decisions.

Because we so seldom see self-directed learners in our college classrooms, we forget how effectively some individuals do learn on their own. Whether it's a self-taught gardener, bird enthusiast, master knitter, or garage-based boat builder, some learners take their avocations to high levels of knowledge and skill. Many of the characteristics of independent learners have been identified through research that analyzes how these self-taught learners operate. This and other research is summarized in a 1991 book by Candy, *Self-Direction for Lifelong Learning*. An appendix contains Candy's Profile of the Autonomous Learner, which lists over one hundred "attributes, characteristics, qualities, and competencies" (p. 459) used by and in research to describe the autonomous learner. This appendix ends up being a unique summary of the research and an apt description of the "perfect" student, the one we'd all love to teach.

Zimmerman (2002), who has also done extensive research in this area, offers a clear definition of what he calls self-regulated learning. He says it is "not a mental ability or an academic performance skill; rather it is the self-directive process by which learners transform their mental abilities into academic skills" (p. 65). This characteristic of learners is variously named: self-directed learners, autonomous learners, independent learners. The differences, more subtle nuances than substantive distinctions, coalesce
in what Zimmerman (2008) describes as the overarching research question: trying to understand "how students become masters of their own learning processes" (p. 166).

Zimmerman’s 2002 article offers a succinct and clear overview of research on self-regulated learning. It’s definitely worth consulting if this area of interest. He identifies three findings that have emerged out of this research. First, “self-regulated learning involves more than detailed knowledge of a skill; it involves the self-awareness, self-motivation, and behavioral skill to implement that knowledge appropriately” (p. 66). Research also confirms that self-regulation is not a trait that some people have and others don’t. And finally, whether or not a student is motivated, self-regulated learning depends on self-efficacy beliefs and intrinsic interest.

As with deep and surface learning, researchers have developed a number of instruments that they have used to determine the extent to which students are self-regulating. These include the Learning and Study Strategies Inventory (better known as LASSI; Weinstein, Schulte, and Palmer, 1987), the Motivated Strategies for Learning Questionnaire (MSLQ; Pintrich, Smith, Garcia, and McKeachie, 1993) and the Self-Regulated Learning Interview Scale, which uses a structured interview to present students with six study problems to which they verbally respond (Zimmerman and Martinez-Pons, 1986, 1988). Like the deep and surface learning instruments, these instruments are great resources for teachers. If students complete one of them, teachers benefit by discovering the extent to which their students are using self-regulating strategies, and students benefit just as much, if not more, by becoming aware of the strategies they use and more effective alternatives.

Zimmerman (2008) summarizes research on four questions currently being explored empirically. Until recently, researchers have relied on student self-reports of what they are doing when they study. Now there are software programs that enable students to use many of the strategies associated with self-regulation, and those programs allow researchers to track which of the strategies students use as they study. The question is whether congruence exists between those self-reports and the actual use of the strategies. So far, the results are mixed. The second question: If students
use self-regulated learning strategies at home or in the library, for example, does that improve their overall academic achievement? Early research answers are yes. The third question is particularly relevant to learner-centered objectives: Can teachers modify what they do in the classroom in ways that increase self-regulated learning among students? Yes, they can. And finally, what role do students’ motivational feelings and beliefs play in initiating and sustaining changes in their self-regulation of learning? Research now indicates a close relationship between self-regulated processes and sources of motivation.

As a result of research on self-directed learning, many now propose that a formal educational experience should enable learners to identify what they need to know and decide how they will learn it—whether they are confronted with learning tasks in the classroom, at home, on the job, or subsequently throughout life. However, Zimmerman (2002) points out that despite research findings showing conclusively that self-regulation leads to greater academic success, “few teachers currently prepare students to learn on their own” (p. 64). He elaborates: “Students are seldom given choices regarding academic tasks to pursue, methods for carrying out complex assignments, or study partners. Few teachers encourage students to establish specific goals for their academic work or teach explicit study strategies. Also, students are rarely asked to self-evaluate their work or estimate their competence on new tasks” (p. 69).

These approaches that prepare students to learn on their own are inherently a part of learner-centered teaching, which involves students in decision making about learning, encourages collaboration, offers explicit instruction on learning skills, and provides opportunities for self- and peer assessment. The value of having students able to learn for themselves is not something most faculty need research to verify. We know that our students will change jobs, many of them more than once, and that ongoing learning will be a part of every job, indeed of life. It is obvious that the success of our students depends on their ability to be lifelong learners.

Research findings on deep and surface learning, faculty orientations to teaching, and self-regulated learning support the use of learner-centered approaches. The work on faculty orientations
establishes that if teachers’ primary focus is on covering content, students respond by memorizing the material, often with little or no understanding. When teachers are learner-centered, focused on developing understanding of the material and committed to helping students gain mastery over their learning processes, students learn the material at a deeper level and begin managing their learning in ways that lead to their autonomy and independence as learners.

**NOTEWORTHY REVIEWS OF RESEARCH**

Reviews of research summarize and integrate findings, making clearer the status of knowledge within a particular domain. Most of the time reviews are written for those doing the research or with related research interests. Rarely do these reviews explore the implications of findings and even more rarely are reviews written expressly for practitioners. The three reviews in this section are notable exceptions, and all three report on research relevant to learner-centered teaching.

**REVIEW OF RESEARCH ON MOTIVATION**

Most faculty struggle against pervasive amounts of student passivity. How can these students be in college and yet be so unmotivated to learn? All of us who teach poorly motivated students need to know as much as possible about research in this area, and Pintrich (2003), an educational researcher known for his work on motivation, has published an outstanding research review. He considers research relevant to seven key questions about motivation:

1. What do students want?
2. What motivates students in classrooms?
3. How do students get what they want?
4. Do students know what they want or what motivates them?
5. How does motivation lead to cognition and cognition to motivation?
6. How does motivation change and develop?
7. What is the role of context and culture?
Unlike so many reviews, Pintrich spells out instructional implications of the research on motivation. For example, in response to what motivates students in classrooms, Pintrich identifies a set of generalizations supported by the research, beginning with “adaptive attributions and control beliefs motivate students” [in classrooms] (p. 673). In summarizing the research that supports this claim, he writes, “the general trend is that students who believe they have more personal control of their own learning and behavior are more likely to do well and achieve at higher levels than students who do not feel in control” (p. 673). And what “design” principles does he recommend based on this finding? “Provide [students] opportunities to exercise some choice and control.” So what many of us have observed in the learner-centered classroom is supported by the research. When students can make some choices about how they learn, and when they have some control over their learning processes, their motivation to learn increases.

There is much, much more in the Pintrich article. However, I would be less than honest if I said it was easy reading. It’s not, but if gaining a better understanding of the role of motivation in learning is of interest, there aren’t many sources more definitive than this one. And effort expended reading this review is rewarded with clear suggestions on what should be done about the research findings.

**Reviews of Research on Active Learning**

Research on active learning covers a large domain and is as diverse and disorganized as any crazy quilt. The problems begin with the many different definitions for active learning and are exacerbated by all the different strategies to which the active learning label is attached. Then there are the multiple methods used to study the effects of active learning experiences. And finally, some sort of study of active learning has been undertaken in almost every discipline. Who would even attempt to review this domain?

The two reviews I’m about to highlight were authored not by educational researchers, who one might argue are the scholars best positioned to attempt such a review, but by a chemical engineer and a med school physiologist. Neither is a typical review of
research articles, and each is constructed quite differently. Both were written for faculty audiences and, despite their different approaches, both come to the same conclusion. If there are ever any doubts as to what active learning accomplishes or if there’s a colleague who’s yet to be convinced that there’s evidence supporting the claims regularly made about active learning, these articles settle the issue. Both merit discussing further, because active learning is to learner-centered teaching as bread is to butter.

Prince’s review (2004) begins with definitions and follows with an excellent discussion of what makes the research on active learning so difficult to consider collectively. For example, there’s the problem of defining what’s being studied. He uses Problem-Based Learning as an example. It’s an approach that has been widely used and studied, but there is no agreement as to the core elements of this strategy, which makes generalizing from the various studies difficult. Then there’s the problem of measuring “what works.” Assessing that “requires looking at a broad range of learning outcomes, interpreting data carefully, quantifying the magnitude of any reported improvement and having some idea of what constitutes a ‘significant’ improvement” (p. 225).

Using clear definitions and establishing qualifying criteria, Prince looks at two major categories of research on active learning: (1) active learning strategies that get students involved in lectures and (2) student engagement activities, including collaborative learning, cooperative learning, and problem-based learning. His reviews of research in each of these areas are clear and easy to understand. For an overall conclusion, he writes, “although the results vary in strength, this study has found support for all forms of active learning examined” (p. 229). A bit later he observes: “Teaching cannot be reduced to formulaic methods and active learning is not the cure-all for all educational problems. However, there is broad support for the elements of active learning most commonly discussed in the educational literature and analyzed here” (p. 229).

Michael’s review (2006) also begins with definitions—for active learning and student-centered instruction. The definition for active learning, from the Greenwood Dictionary of Education, indicates that it is a “process of having students engage in some activity that forces them to reflect upon ideas and how they are
using those ideas." It continues with a list offering examples: "Requiring students to regularly assess their own degree of understanding and skill at handling concepts or problems in a particular discipline. The attainment of knowledge by participating or contributing. The process of keeping students mentally, and often physically, active in their learning through activities that involve them in gathering information, thinking and problem solving" (p. 160).

That's a noteworthy definition for a couple of reasons. First of all, there is a tendency among faculty to think that active learning is about activity—getting the students to do something. What they are doing matters less than the fact that they are no longer passive. This definition makes clear that when the word "active" is combined with "learning," what students are doing matters. They should be engaged in activities that involve reflection, assessment, and learning tasks associated with mastery of the material. Said differently, not all things called active learning are focused on learning. Learner-centered teachers are interested in those that are learning-centered.

Michael (2006, pp. 160–165) includes in his review evidence from the learning sciences, cognitive science, and educational psychology. He distills the research from those fields into five principles, which he describes as "key findings" that support active learning:

- Learning involves the active construction of meaning by the learner. Learners construct meaning by combining what they currently know with the new information they are acquiring. This makes learning a personal process and rules out any idea of learning as the mere transmission of knowledge.
- Learning facts and learning to do something are two different processes. This explains how students can know the facts and still not be able to do anything with that information.
- Some things that are learned are specific to the domain or context (subject matter or course) in which they were learned, whereas other things are more readily transferred to other domains. In order to successfully transfer knowledge from one situation to another, students need to practice.
- Individuals are more likely to learn more when they learn with others than when they learn alone.
• Meaningful learning is facilitated by articulating explanations, whether to one’s self, peers, or teachers. Constructing these explanations also gives students practice in using the language of the disciplines.

His review includes a section that highlights evidence that active learning works in the sciences. He explains how educational research is different from research done in the sciences and why teaching and learning phenomena are difficult to study. He concludes, “There is evidence that active learning, student-centered approaches to teaching physiology work [the evidence he summons supports this as a general conclusion], and they work better than more passive approaches” (p. 165).

**DISCIPLINE-BASED RESEARCH IN SUPPORT OF LEARNER-CENTERED APPROACHES**

Some of the best discipline-based research in support of learner-centered approaches involves three highly structured forms of group work, and most of the research on their effectiveness has been done in the sciences. A fine article describes and compares these pedagogies of engagement: Problem-Based Learning (PBL), Process-Oriented Guided Inquiry Learning (POGIL), and Peer-Led Team Learning (PLTL; Eberlein, Kampmeier, Minderhout, Moog, Platt, Varma-Nelson, and White, 2008). These are by no means the only group structures that incorporate learner-centered strategies. Prince and Felder (2006, 2007) offer two comprehensive reviews of what they call inductive teaching and learning methods which, in addition to the three group structures I’m summarizing here, include Project-Based Learning, Case-Based Teaching, Discovery Learning, and Just-in-Time Teaching. The Prince and Felder articles are full of references that describe programs using all these group structures as well as empirical studies of their effectiveness.

Problem-Based Learning (PBL) was first used in medical education. Groups of medical students tackled an open-ended problem, often a patient with a variety of confusing symptoms. In
PBL, the problem comes first, which means students learn content on a need-to-know basis. As it was developed, PBL was a lectureless pedagogy. In the years since its introduction, PBL has been used widely in many fields beyond medicine. With undergraduates, the problems are messy; real-world situations that require students to integrate knowledge across courses and sometimes even from several fields. Wider use has also prompted the development of different forms of PBL, making it difficult to compare research results.

Process-Oriented Guided Inquiry Learning, which usually goes by the acronym POGIL, originated in chemistry and involves students working together during class on specially designed materials. They work through a set of carefully crafted questions, the guided inquiry, which follow a three-phase “learning cycle.” First students explore, then they invent, and finally they apply. Examples of POGIL materials as well as references and other resources can be found at this website: www.pogil.org. Instructors function as facilitators, supporting the groups in a variety of ways and occasionally presenting material in lecture format. Students are assigned roles such as manager, scribe, spokesperson, or librarian. This approach has been used with undergraduates in chemistry, physics, math, computer science, engineering, environmental science, education, anatomy and physiology, and marketing.

Peer-Led Team Learning (PLTL) also originated in chemistry. It involves the use of trained student facilitators—students who have completed the course with high grades. These student facilitators, or peer leaders, meet once a week for two hours with six to eight students currently enrolled in the course. They work on faculty-prepared problems related to text material, lectures, and homework problems. The peer leaders encourage students in the groups to use collaborative learning approaches such as brainstorming, round-robin problem solving, reciprocal questioning, and forms of think-pair-share. In some cases, the PLTL sessions occur entirely outside of class, sometimes they replace a regularly scheduled recitation session, and in other cases one hour of lecture per week is eliminated to make time for the PLTL session.
The Eberlein, Kampmeier, Minderhout, Moog, Platt, Varma-Nelson, and White article (2008) contains a detailed table that compares and contrasts these three approaches. They say that of the three, "PLTL involves the least and PBL the greatest departure from traditional instruction" (p. 270). Given the characteristics of learner-centered teaching, all three qualify as learner-centered approaches, although that label is not regularly attached to them in the literature. Students are actively engaged with the material, they have varying degrees of control over the learning processes, and they are not only learning material, but learning processes like how scientists approach and solve problems. Each of the methods has been studied empirically, and a summary of findings for each of the three follows.

**Problem-Based Learning**

PBL is the oldest, most widely used, and most well researched of these three group structures. Several review articles on PBL have been published: Vernon and Blake (1993) looked at thirty-five medical school studies of PBL published between 1970 and 1992, Albanese and Mitchell (1993) reviewed literature on implementation and outcomes, again in medical education. Dochy, Segers, den Bossche, and Gijbels (2003) did a meta-analysis of forty-three studies of PBL, including a number that were conducted in disciplines other than medicine.

In the literature, definitions of PBL are fairly consistent, but at the point of implementation, much variation occurs. Prince (2004) explains why this is a problem: "The large variation in PBL practices makes the analysis of its effectiveness more complex. Many studies comparing PBL are simply not talking about the same thing. For meta-studies of PBL to show any significant effect compared to traditional programs, the signal from the common elements of PBL would have to be greater than the noise produced by differences in the implementation of both PBL and the traditional curricula" (p. 228). This caveat should be kept in mind whether we are considering PBL studies collectively or individually, and it helps to explain the inconsistency in results across studies.
Even so, the research results should not be ignored, as they do document important outcomes that occur when students work collectively on solutions to PBL problems. Vernon and Blake (1993) report improved student attitudes about their programs and a statistically significant improvement of PBL students in clinical performance, although some have argued with that finding. The Dochy, Segers, den Bossche, and Gijbels (2003) review finds a “robust positive effect from PBL on the skills of students.” They use the library more, read their textbooks more, have better class attendance, and study for meaning instead of memorizing. Prince and Felder (2006) describe the results of the Dochy, Segers, den Bossche, and Gijbels analysis as “unequivocal: 14 studies found a positive effect and none found a negative effect... The positive effect of PBL on skill development holds regardless of whether the assessment is concurrent with the instruction or delayed” (p. 129). It is not surprising that PBL develops skills so effectively. It is a learner-centered method that puts students much more in charge of their own learning.

But not all the findings on PBL are positive. Some studies (seven out of ten in the Albanese and Mitchell, 1993, review) report that students in PBL programs scored lower than students in traditional programs on tests of science knowledge (remember that the reference here is medical education). Dochy, Segers, den Bossche, and Gijbels (2003) report a similar finding, but describe the overall effect of PBL on knowledge acquisition as “non-robust” (p. 533). Prince and Felder (2006) elaborate: “When only true randomized tests are included, however, the negative effect of PBL on knowledge acquisitions almost disappears, and when the assessment of knowledge is carried out some time after the instruction was given, the effect of PBL is positive. The implication is that students may acquire more knowledge in the short term when instruction is conventional but students taught with PBL retain the knowledge they acquire for a longer time” (p. 129).

Prince (2004) offers this summary of PBL research overall: “While no evidence proves that PBL enhances academic achievement as measured by exams, there is evidence to suggest that PBL ‘works’ for achieving other important learning outcomes. Studies suggest that PBL develops more positive student attitudes, fosters
a deeper approach to learning and helps student retain knowledge longer than traditional instruction” (p. 229).

**PROCESS-ORIENTED GUIDED INQUIRY**

Process-Oriented Guided Inquiry (POGIL) has been used by over one thousand teachers. It has also received $2 million in National Science Foundation funding, as well as other grant support. Research on this learner-centered group strategy contains an equally impressive list of results. For starters, it improves academic performance. Here are a couple of examples. In a first-year anatomy and physiology course (J.P.P. Brown, 2010) where 50 percent of the lectures were replaced with in-class POGIL activities, overall course scores increased from a mean score of 76 percent to 89 percent. And scores on the same multiple-choice final increased from a mean of 68 percent to 88 percent. The rate of students earning Ds or Fs dropped significantly as well. In a medicinal chemistry course (S. D. Brown, 2010) where students spent approximately 40 percent of their time working collectively on guided inquiry materials, mean exam scores for students in the two guided inquiry sections were almost 3 percentage points higher than students in the traditional section, and the final grade distribution in the POGIL sections were in the A to B range, compared with the other section, where grades were in the B to C range. And finally, in a professional selling course in marketing, faculty researchers (Hale and Mullen, 2009) document these results: “This innovative teaching method has reduced absenteeism, motivated students to become active learners and increased student performance in our classes” (p. 73).

Researchers consistently report that student attitudes toward the approach are positive, with students saying that working through materials with other students helps them understand the content better. In one study (Straumanis and Simons, 2008) involving over one thousand students at a number of different institutions, fewer than 8 percent of the students were negative about the approach. This compared with 30 percent who reported negative attitudes toward traditional lectures. In another analysis (Minderhout and Loertscher, 2007), 80 percent of the students...
said that aspects of POGIL experiences such as group problem solving and skill exercises helped their learning.

J.F.P. Brown offers this summary: “Although POGIL requires a great deal of effort and a careful introduction to students who might be skeptical of a novel and unfamiliar classroom experience, its benefits cannot easily be disputed” (2010, p. 155).

PEER-LED TEAM LEARNING

Since its development in the early 1990s, this strategy has been used widely across a range of institutions including community colleges and research universities. Gosser, Kampmeier, and Varma-Nelson (2010), the early developers of the approach, write that they ultimately “lost count of the number of PLTL (peer-led team learning) implementations, but a conservative estimate is that at least 200 faculty from more than 150 institutions are implementing PLTL, with 2,000 trained leaders conducting workshops for over 20,000 students per year” (p. 376). Early on, the developers assessed the effectiveness of this group structure by looking at student success in the general chemistry course for which it was developed. The percentage of students receiving As, Bs, or Cs in that course increased from 38 percent to 58 percent. Many of those implementing the approach have also tracked its impact on student success, and the overall average increase in the percent of students receiving As, Bs, and Cs is 14 percent.

More convincing than the reported increases in grades are the results of a variety of carefully controlled and empirically robust studies (Tien, Roth, and Kampmeier, 2002; Bacz-Galib, Colon-Cruz, Resto, and Rubin, 2005; Lewis and Lewis, 2005; McCreary, Golde, and Koeske, 2006; Wamser, 2006; Hockings, DeAngelis, and Frey, 2008; Lyon and Lagowski, 2008). All of these studies report positive results for students who participated in the peer-led sessions.

Studies of this group method address one of the major objections faculty raise when considering learner-centered approaches: “I won’t get the content covered, and that means students won’t learn as much.” In their Lessons Learned section, Gosser, Kampmeier, and Varma-Nelson (2010) conclude: “Lecture can be reduced without compromising content if the time is spent on
activities that promote active engagement of the students with the subject matter and with each other" (p. 378). The studies referenced above support this claim in a variety of different ways. Here's one illustration: Lewis and Lewis (2005) used the PLTL model in a general chemistry course. In their experimental group, 100 students had two fifty-minute lectures per week and one fifty-minute peer-led session. In the control group, 190 students had three fifty-minute lectures. Students in both groups took the same four exams and final. Students in the experimental group had higher mean scores on every exam, including the final: "fears that students who had less exposure to lecture would learn less proved to be groundless in this study" (p. 139). Given the chance to continue the PLTL sessions in the second semester of the course, 85 percent of the students said they would and 76 percent of them believed that working in the group was beneficial. Only five (of the experimental group) reported that the group slowed them down.

Before concluding this section, I would like to highlight one more study of unstructured group collaboration. This study, done in chemistry (Cooper, Cox, Nammouz, and Casc, 2008), looked at how work in groups affected problem-solving strategies and abilities. The study used a software system that allowed researchers to follow how students moved through a problem and model their progress as they worked on multiple problems. Based on earlier research, this team knew that students "stabilize," or settle on a strategy or approach, after working on about five versions of the problem. They wanted to know whether working in a group would change the "stable" strategies of individuals, particularly the less effective strategies.

The findings were quite remarkable. Using over 100,000 performances by 713 students, "we have shown that we can improve student problem solving by having students work in collaborative groups. These improvements are retained after grouping and provide further evidence of the positive effects of having students work in groups" (p. 871). Researchers found that most students improved by a factor of about 10 percent, including many of the students who had previously settled on ineffective strategies.

Why does working with others have such a positive influence on problem solving, an influence strong enough to remain even
after the group member has returned to individual problem solving? The research team suggests some reasons. First, in groups students have to explain things to each other. That articulation helps those who hear it and those who make it. In a group, students must elaborate and critique each other. That further analysis aids understanding.

The evidence highlighted here and more like it offer convincing evidence that students can learn from and with each other in a variety of group structures. Many of the results document significant gains in content knowledge. Virtually all of them document important gains in the development of skills like questioning, critical thinking, problem solving, and knowledge integration and application. The evidence makes it difficult to explain why more faculty are not using learner-centered approaches like these.

STUDIES OF INDIVIDUAL LEARNER-CENTERED COURSES

Highlighted in this section are studies of individual courses in which a collection of different learner-centered strategies were implemented and empirically analyzed. In most cases, the learner-centered version of the course can be compared with previous or current sections of the course where the approaches were not used. The studies also illustrate different kinds of courses where learner-centered approaches have been incorporated, such as large courses.

SIX STUDIES OF BIOLOGY COURSES

An impressive amount of research has been done on mostly large and mostly introductory biology courses. These are well-designed studies with findings that deserve to be taken seriously. Faculty often dismiss pedagogical research not done in their discipline, and while it is true that we cannot be certain that the methods tested in one field will work with different content, a different teacher, and different students, most of the methods used in these studies are common ones—ones that are being used with many different kinds of content. The other very encouraging aspect of this work in biology is its response to the common faculty question
of whether you can use learner-centered approaches in large classes. The brief highlights that follow include changes in overs, overview of the learner-centered strategies, and approaches incorporated and the results.

Armbruster, Patel, Johnson, and Weiss (2009) describe a series of changes implemented in 170- to 190-student introductory courses for biology and premed majors. Their course redesign consisted of three elements: they reordered the course content so that it could be taught as broad conceptual themes; they incorporated active learning (including clickers with participation points for answers) and group problem solving into every lecture; and they worked to create a more student-centered learning environment with course goals, helpful vocabulary handouts, and formative weekly quizzes. These changes significantly improved student satisfaction with the course including levels of interest in the course material, self-reported learning, ranking of classroom presentations as stimulating, and the overall evaluation of the instructor. As for academic performance, the same final exam questions had been used in a section of the course taught without these changes. Students in the redesigned course performed at statistically significant higher levels: “our positive results illustrate how changing the instructional design of a course, without wholesale changes to course content, can lead to improved student attitudes and performance” (Armbruster, Patel, Johnson, and Weiss, 2009, p. 204).

In another one-hundred-student general biology course, the professor (Burrowes, 2003) instituted a number of group learning strategies including regular problem-solving activities completed in the groups during class, a quizzing mechanism where one group member took the quiz for the group, a group test-retake with a small bonus point incentive, and a number of other changes involving how content was presented in class. This experimental section was compared with a similar-sized section taught using a traditional lecture approach. Students in the experimental section out-performed students in the control section at statistically significant levels on all three exams. They also out-performed students in the control section at statistically significant levels on questions testing conceptual understanding, which led the professor to conclude that “in-class practice of problem-solving techniques does
help to develop skills for scientific thinking” (Burrowes, 2003, p. 498). They did better on the test-retake activity, and their attitude toward biology was significantly better than those in the control group.

Freeman, Haak, and Wenderoth (2011) tested whether highly structured course designs that included reading quizzes, extensive in-class active-learning activities, and weekly practice exams could lower the failure rate in an introductory biology course for majors. The course was offered every quarter and enrolled almost 2,100 students the year during which the study was completed. These experimental sections were compared with primarily lecture-based sections with fewer exams. “When we controlled for variation in student ability, failure rates were lower in a moderately structured course design and were dramatically lower in a highly structured course design” (p. 175). They also report that they “found no evidence that points for active-learning exercises inflate grades or reduce the impact of exams on final grades” (p. 175).

Knight and Wood (2005) modestly changed an upper-division lecture course on developmental biology. They still lectured 60 to 70 percent of the time, but the rest of the time students did problem solving, using a cooperative learning model. As for results, their findings suggest “that even a partial shift toward a more interactive and collaborative course format can lead to significant increases in student learning gains” (p. 304).

They use these results to “propose a general model for teaching large biology courses that incorporates interactive engagement and cooperative work in place of some lecturing, while retaining course content by demanding great student responsibility for learning outside the class” (p. 298).

Ueckert, Adams, and Lock (2011) report on a major redesign of an entry-level course for majors. This biology course enrolls nine hundred students in the fall and five hundred in the spring. It is taught in three to five sections by a variety of instructors. Redesign tasks included development of a common syllabus, a table of specifications (which identifies key concepts, desired skill levels, and amount of time devoted to each concept), and a course assessment tool. They incorporated a variety of learner-centered activities including think-pair-share, clickers, and small-group work, all described in detail in the article. They collected and analyzed data from three years before the change and for three
years after it. The percentage of students who dropped the course decreased by statistically significant amounts, and the percentage of As and Bs increased, also by statistically significant amounts. They use the adjectives “long,” “slow,” and “challenging” to describe this revision process.

Derling and Ebert-May (2010) were interested in a different kind of research question: “Is the infusion of two new introductory courses early in a student’s curriculum, both based on learner-centered inquiry-based principles, associated with long-term understanding of biological concepts and biology as a process of inquiry?” (p. 463). They note that most studies analyzing the impact of learner-centered course revisions focus on short-term changes. Did final exam scores improve, was there evidence of skill development, or did student attitudes about the course change? Derling and Ebert-May “studied a revised biology curriculum implemented at the beginning of the biology major” (p. 463). The revision involved development of two new courses, both using a number of different active-learning and inquiry-based approaches. In one of the courses, students posed their own research questions and hypotheses. They developed research proposals and critiqued those of their peers. They collected and analyzed data and presented their findings.

The researchers employed two assessment tools to ascertain the impact of the new courses across a five-year period. They assessed student understanding of biology as a process of inquiry (using a Views about Science Survey for Biology) and student knowledge of biological concepts at the end of the major (using a version of the Major Field Test in Biology). Simply put, their results “showed that an intense inquiry-based learner-centered learning experience early in the biology curriculum was associated with long-term improvements in learning” (p. 462). “Transformation of introductory biology curricula . . . through learner-centered inquiry-based teaching may have the potential to profoundly impact learning by all students and even become a tipping point for departmental change” (p. 471).

**STUDY OF AN ALGEBRA COURSE**

At the University of Missouri-St. Louis college, algebra—required for several majors, a prerequisite for calculus, and a key course
for students in math, science, business, and a variety of paraprofessional programs—had a success rate of 55 percent (Thiel, Peterman, and Brown, 2008). Faculty redesigned the course. The three fifty-minute lecture periods were reduced to one and were replaced with two computer-lab sessions, where students learned math by doing math. In the labs students used software that included explanations, tutorials, practice problems, and guided solutions. They could also do their homework in the lab, collaborating with other students or soliciting help from the instructor, a graduate student, or peer tutor (one of whom was present during the scheduled lab sessions). Students also took weekly online quizzes, four exams, and a comprehensive final.

“The redesign has significantly changed the role of the instructors and teaching assistants. They used to spend their time lecturing, writing assignments and exams, and grading. Now they focus on guiding students through the course via the weekly meeting in a lecture room and then working individually with students in the [math technology] learning center. The greater emphasis on individual instruction and one-on-one interactions with students is a change that most instructors find very rewarding” (pp. 46–47).

As for the results, over a three-year period student success improved from 55 percent to 75 percent, “with no decrease in course rigor, as demonstrated by student scores on a final exam that included the same types of problems during the redesign period as before it” (p. 46).

STUDIES IN PHYSICS COURSES

Some years before there was much work at all on learner-centered approaches, specifically peer learning. Harvard physicist Eric Mazur (2009) had dramatically changed the way he taught and was collecting data on its effects. He describes his approach giving students “the opportunity to resolve misunderstanding about concepts and work together to learn new ideas and skills in a discipline” (p. 51). Of the findings from his work and those who have replicated his approach, he writes: “Data obtained in my class and in classes of colleagues worldwide, in a wide range of academic settings and a wide range of disciplines, show that learning
gains nearly triple with an approach that focuses on the student and on interactive learning” (p. 51). This short article, which recounts the transformation of his pedagogical approach, includes references to the studies that support his claims of significantly improved learning outcomes.

For a very specific example of another learner-centered approach used in physics, consider this study of two large sections (N = 267 and N = 271) of the second term of a first-year physics sequence. Sections were compared to see if “deliberative practice” improved student learning (Deslauriers, Schelew, and Wieman, 2011). Deliberative practice (a cognitive psychology concept) in this course took the form of “a series of challenging questions and tasks [that] require the student to practice physicist-like reasoning and problem solving during class time while provided with frequent feedback” (p. 862). Students in the experimental section used deliberative practice for one week, learning the same content that was being covered by lecture in the control section. “We found increased student attendance, higher engagement and more than twice the learning in the section taught using research-based instruction” (p. 862).

The studies described in this section illustrate what happens when a variety of learner-centered strategies are incorporated in a course. Positive results on learning outcomes were reported for large courses, for beginning courses, for courses with high failure rates, for major courses, and for required courses. The results were positive even when a small number of changes were implemented, and the results were enduring when the course design changes were substantial.

WHAT DO STUDENTS SAY ABOUT LEARNER-CENTERED APPROACHES?

Faculty using learner-centered approaches frequently experience student resistance, a topic dealt with at length in Chapter Eight. Initially, students want learner-centered teachers to do what teachers do in many other courses—tell them everything they need to know about the content and their assignments. Do students ever come around? At some point do they begin to see that what teachers are trying to do actually helps them learn the material? Of the
studies reported in the previous two sections, many of the researchers did solicit responses from students as to the merits of these various learner-centered approaches, and uniformly the student response was positive. In many cases, students reported that they struggled with the new approaches initially, but as their experience with them accumulated, they did find them beneficial.

Supporting that response, but with a bit more detail, is a descriptive analysis (Terenzini, Cabrera, Colbeek, Parente, and Bjorklund, 2001) that compared the experiences of engineering students enrolled in courses that were part of a National Science Foundation project (Engineering Coalition of Schools for Excellence in Education and Leadership, or ECSEL) with the experiences of students in regular engineering courses. The project aimed to improve undergraduate engineering courses by incorporating active and collaborative learning experiences.

Survey data were collected from 339 students in seventeen ECSEL courses at six different institutions and from 141 students in six non-ECSEL courses. Among other questions, the survey asked whether students believed that they had made progress in a variety of learning and skill development areas as a result of taking that particular course.

Students in the ECSEL courses reported significant advantages: "ECSEL students reported learning advantages in three areas: design skills, communication skills, and groups skills. The advantages enjoyed by ECSEL students were both statistically significant and substantial" (p. 129). For example, ECSEL students reported learning gains in communication skills 11 percentile points higher than their peers in the non-ECSEL courses; in design skills ECSEL students reported learning gains 23 percentile points higher; and in group skills they reported gains 34 percentile points higher. "These learning advantages remained even when differences in a variety of student pre-course characteristics were controlled" (p. 123).

CONCLUSION

Sometimes it is best to let the evidence speak for itself, and this chapter may be one of these cases. We’ve covered a lot of territory here and explored what seems to me is a convincing body of evi-
dence supportive of the learner-centered approaches advocated in this book. I am happy to let the evidence speak for itself, confident that faculty readers can review, critique, and evaluate it.

However, I am not going to close the chapter without raising the question asked by an impressive group of science educators and academic leaders (Handelsman, Ebert-May, Beichner, Bruns, Chang, DeHaan, Gentile, Lauffer, Stewart, Tilghman, and Wood, 2004) in the prestigious publication *Science*. Their audience is scientists, but the question can be asked of any academic scholar: “Why do outstanding scientists who demand rigorous proof for scientific assertions in their research continue to use, and indeed defend, on the basis of intuition alone, teaching methods that are not the most effective?” (p. 521). I suggested some answers in the chapter’s introduction. Maybe they don’t know there is research, or they don’t read the research—maybe they’ve tried and found it difficult to understand—or perhaps they don’t think the research is very good. This chapter is an attempt to challenge the legitimacy of those reasons so that the question realizes its powerful potential and motivates changes in practice.