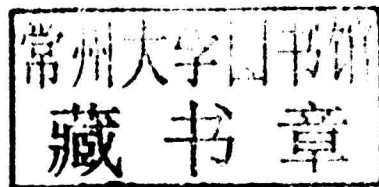


Molecular and Quantitative Animal Genetics

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Decoding and Encoding the “DNA” of Teaching and Learning in College Classrooms

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Introduction

The success of the human species on Earth has derived in part from its ability to understand, predict, manipulate, govern, and preserve biological lifecycles from the microscopic to the planetary scale. Since the rediscovery of Mendel’s work at the beginning of the twentieth century, the mechanisms of inheritance and nature versus nurture have been enduring themes for geneticists. What a living organism (plant, animal, or microbe) exhibits, its recorded performances, and its observed behaviors, depends in part upon the inherited genes, the environment, and their interactions. At the molecular level, the deoxyribonucleic acid (DNA) encodes the genetic instructions. The DNA, organized in chromosomes, is found in the nucleus of cells that make up tissues and organs, which in turn contribute to the proper functions of the organism as a member of a species in constant dynamic equilibrium with other components of an ecosystem. Irrespective of the unique contribution of molecular biology, cellular and organismal physiology, ecology, and evolution to the field of biology as a whole, DNA is the molecule that fundamentally connects these disciplines to each other. Is there such a thing as the “DNA” of teaching and learning? What are the fundamental structures and processes that underpin the education of human beings? Could one look at kindergarten, primary, secondary, and higher education, the household, the workplace, the places of worship, the public squares, and public libraries as places of teaching and learning that form a continuum made of distinct but interacting parts in one’s life, and the life of human communities? Could we think of these parts as forming cultural heritages and educational traditions that humans pass on from one generation to the next? If so, what are the roles of institutions of higher education and what are their functions? What educational purpose do they serve when four years on a university campus is approximately 5% of one’s lifespan (Figure 1.1)? Is a scientific fact to critical thinking what DNA is to a gene? Could we imagine teaching and learning as the two complementary strands of a DNA molecule where the information that has been acquired by previous generations is stored and preserved, but where mechanisms for change during duplication are essential to allow for adaptation to changing conditions?

In this chapter we have attempted to address what students do when they learn and what teachers do when they teach at a

fundamental level. Our goal was to summarize the current literature only to the extent necessary to challenge long-held views about the role of the instructor, the role of the student, and the traditional instructional design of a college classroom. We hope that by analyzing definitions, exploring theories of learning, and reviewing teaching-related institutional reforms, we have created a context and laid the foundation for a deeper understanding of an instructor’s role as the designer of a learning environment. The overarching aim is greater fulfillment and reward for both the instructor and the students as they engage in a college classroom intended to equip the latter for a successful career in the twenty-first century.

Teaching and learning: definitions

Teaching and learning are multifaceted and closely related concepts as revealed in the subtleties of their multiple definitions (Table 1.1 and Table 1.2). A close look at these definitions shows the intricacies of the relationships between teaching and learning. For example, although teaching – the act, practice, or profession of a teacher – is to cause to know, to impart knowledge or skills; to teach is also defined as to accustom to some action or attitude (item 1c, Table 1.1) or to guide a study (item 2, in Table 1.1). Not surprisingly, knowledgeable individuals are not the only sources of teaching. One’s own experience can be a “teacher” (item 4b, Table 1.1). Similarly, experience may cause learning to occur. To learn – to gain knowledge, understanding of, or skill in – can be completed by the self, by instruction or by experience as illustrated in Table 1.2 items 5a, 5b, and 5c, respectively. The verbs describing teaching and learning are important because they reflect and reveal aspects of the two contrasting, yet complementary, learning theories that will be discussed next: **behaviorism** and **constructivism**. Although the former implies a cause and effect relationship between teaching and learning, the latter describes the relationship in broader associative terms. For example item 5c (Table 1.2) and item 4b (Table 1.1) can be combined to reflect a constructivist approach to learning that emphasizes mental processes: “First year college is a *learning* experience that *taught* us our limitations.”

These definitions reveal the diversity of interpretation, and highlight the complexity of the transactions that take place in the classroom. Similarly, the adherence to either learning theory has

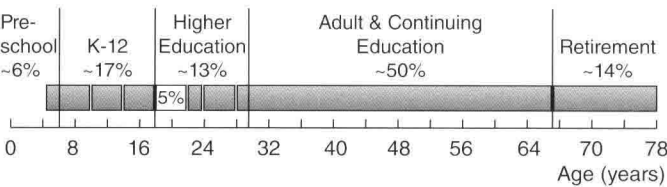


Figure 1.1 Educational stages across the lifespan of a citizen of the United States with an average life expectancy at birth of 78 years.

Table 1.1 Definitions¹ of the verb *to teach* and the noun *teaching*.

Definitions of "to teach"

1a To cause to know something <taught them a trade>
1b To cause to know how <is teaching me to drive>
1c To accustom to some action or attitude <teach students to think for themselves>
1d To cause to know the disagreeable consequences of some action <I'll teach you to come home late>
2 To guide the studies of
3 To impart the knowledge of <teach algebra>
4a To instruct by precept, example, or experience
4b To make known and accepted <experience teaches us our limitations>
5 To conduct instruction regularly in <teach school>

Definitions of "teaching"

6 Teaching: the act, practice, or profession of a teacher
7 Teaching: something taught (the ideas and beliefs that are taught by a person); especially doctrine <the teachings of Confucius>

¹Source: Merriam-Websters Dictionary www.merriam-webster.com/.

Table 1.2 Definitions¹ of the verb *to learn* and the noun *learning*.

Definitions of "to learn"

1a To gain knowledge or understanding of or skill in by study, instruction, or experience <learn a trade>
1b To memorize <learn the lines of a play>
2 To come to be able <learn to dance>
3 To come to realize <learned that honesty paid>
4² To become informed of; find out <learned about the latest findings>

Definitions of "learning"

The activity or process of gaining knowledge or skill:
5a by studying, practicing, <Learning ought to be fun>
5b by being taught <the study guides helped my learning>
5c by experiencing something <First year in college is a learning experience>
6 Sum of knowledge or skill acquired by instruction or study <They were people of good education and great learning>
7 Modification of a behavioral tendency by experience (as exposure to conditioning)

¹Source: Merriam-Webster's Dictionary www.merriam-webster.com/.

²Source: The Free Dictionary www.thefreedictionary.com/learn.

profound implications on classroom instructional design and the role played by the instructor and the students therein. For example, unidirectional approaches to teaching have been recognized as providing sub-optimal learning experiences for most students. Quoting the work of educational psychologists (Bloom et al., 1956) who developed a classification of learning objectives

to create more holistic forms of education, Kauffman et al. (1971) pleaded with his colleagues in the animal sciences more than 40 years ago to be mindful of their classroom design as they wrote:

Education experiences in a course should include the recognition of cognitive domain (objectives which deal with ... knowledge and intellectual abilities and skills), the affective domain (objectives which describe changes in interest, motivation attitudes, values and aspirations) and the psychomotor domain (objectives which emphasize manipulation of materials or objects or action which requires neuromuscular coordination).

In addition to these three domains, researchers have recognized the importance of reflection as an essential component of learning (Kolb, 1984). The awareness or analysis of one's own learning or thinking processes, referred to as **metacognition**, has been incorporated in a recently revised version of the taxonomy of learning that identified four knowledge dimensions and characterized them as follows (Anderson and Krathwohl, 2001; Krathwohl, 2002):

- **Factual knowledge:** The basic elements that students must know to be acquainted with a discipline or solve a problem in it;
- **Conceptual knowledge:** The interrelationships among the basic elements within a larger structure that enable them to function together;
- **Procedural knowledge:** How to do something; method of inquiry, and criteria for using skills, algorithms, techniques, and methods;
- **Metacognitive knowledge:** Knowledge of cognition in general, as well as awareness and knowledge of one's own cognition.

Understanding learning

Research in learning

Historically, the data on how people learn have come from the field of educational psychology, which is the study of how humans learn in educational settings. Most of the current recommendations and "best teaching practices" have been derived from more than 100 years of research in child development and efforts to bring learning research into the primary and secondary education ("K-12") classrooms (Bransford et al., 2000). The insights gained from research addressing issues of gender and ethnicity, and specialized fields of investigation targeted at gifted students, students with disabilities, or students from diverse socioeconomic backgrounds have contributed substantially to creating more inclusive and effective learning environments for all. Measures of teaching and learning success have included students' score on standardized tests, reduction in achievement gaps (differential grades of students "at-risk"), and years to graduation and dropout rates. However, there are numerous reasons to caution against simple extrapolation of the K-12 literature to the university classroom. As illustrated in Figure 1.1, college students are in transition from late adolescence ("teenagers") to young adulthood, and thus, in creating learning environments for their students, university instructors may take heed of the emerging literature on adult and continuing education (Cross, 1981; Kazis, 2007) and adult learning theory (Merriam, 2001; 2008). Research in adult and continuing education has focused not only on skills required of individuals interested in promotion within their organization

or engaged in career changes but also on meta-objectives such as the understanding that knowledge is neither given nor gotten, but constructed; the ability to assess one's own beliefs; and the realization that learning is a worthy lifelong goal (Taylor and Marienau, 1997). Notably, some of these goals are in alignment with the set of “essential learning outcomes” put forth by the American Association of Colleges and Universities for four-year undergraduate programs in the United States (AAC&U, 2012).

Decisions made by teachers in designing their classroom instructions emerge from their own explicit or implicit adherence to certain views in regards to the nature of teaching and learning. At the risk of oversimplification, we will distinguish in the next sections between two broad theoretical traditions in regards to the fundamental ways by which learning occurs: behaviorism and constructivism. Our attempt is not to describe these theories (which are typically taught in educational psychology courses), but rather the conditions required to make learning happen as implied by the theories.

Behaviorism

The behaviorist views of learning emphasize dualisms: giver and receiver, stimuli and response, right and wrong, reward and punishment. At its roots, behaviorism emerged from early research that succeeded in conditioning (i.e., “training”) animals to a certain reflex behavior (a response) from sufficiently repeated pairings with a stimulus, which previously did not elicit the response. This type of research was pioneered by the Russian physiologist Ivan Pavlov (1849–1936) and has led to what is now referred to as **classical conditioning**. Edward Thorndike (1874–1949), another pioneer of this kind of learning formulated the “Law of Effect,” which implies that behavior that brings about a satisfying effect (reinforcement) is apt to be performed again, whereas behavior that brings about negative effect (punishment)

is apt to be suppressed. Thorndike believed that a neural bond would be established between the stimulus and response. Learning takes place when the bonds are formed into patterns of behavior. However, Burrhus Skinner (1904–1990) considered to be the “grandfather of behaviorism” in educational settings focused on cause-and-effect relationships that could be established by observation, arguing that no scientific measure could address the mental processes that operate in the brain during learning (Roblyer et al., 1997). To Skinner, teaching that brings about learning is a process of arranging effectively “contingencies of reinforcement” or, in other words, arranging situations for the learner in which reinforcement is made contingent upon a correct or desired response. Thus, behaviorists believe that people learn (i.e., change behavior) when stimuli are provided and a voluntary response is either reinforced or punished, a theory referred to by psychologists as **operant conditioning** (Figure 1.2). Teachers and instructional materials are the antecedents/stimuli, whereas the skills that the students demonstrate are the responses/behaviors (Figure 1.2a). Behaviorists concentrate on immediate observable changes in performance (e.g., test scores, athletic level) as indicators of learning and thus they would agree that carefully prepared didactic interactions (e.g., delivery of highly structured lectures), repetition (drills, exercises, practice, etc.) and prompt feedback are important in promoting learning (Figure 1.2b). Skinner believed that high-level capabilities such as critical thinking and creativity could be taught in this way; it was simply a matter of establishing “chains of behavior” through principles of reinforcement.

Behaviorism, however, does not explain all the phenomena observed in learning situations, and as a learning theory it has its limitations. First, it does not account for “internal influences” such as mood, thoughts, and feelings of the learner (i.e., it does not consider internal mental states, emotions, or consciousness).

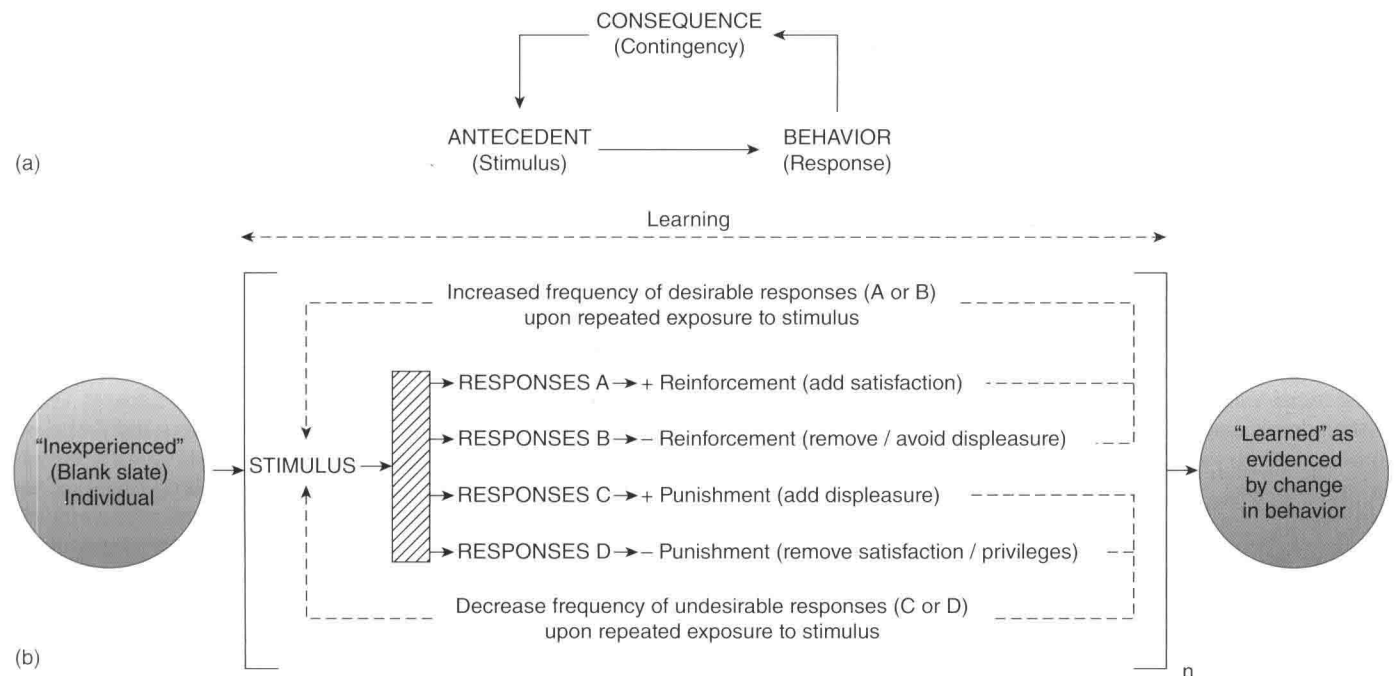


Figure 1.2 Behaviorist approach to learning defined as a measurable change in behavior (response) contingent upon antecedents (stimuli) arranged in a way that alter the frequency of learner-generated trial-and-error responses in which reinforcements are expected to increase the rate of desirable responses and punishments are expected to decrease the rate of undesirable responses.

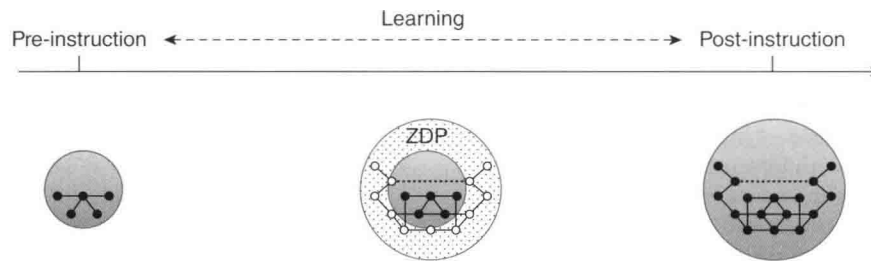


Figure 1.3 Constructivist approach to learning defined as an increasing level of ability in solving complex problem. The zone of proximal development (ZPD) is the area beyond what a student can do alone (blue core circle), but possible with the assistance of a more competent peer or adult with proper temporary scaffolding that helps the learner expand their abilities after internalizing new knowledge and skills (dots), connecting them (lines) into increasingly complex patterns of recognition or abilities.

Second, it does not account for other types of learning that occur without the use of reinforcement and punishment, such as learning based on intrinsic motivation (i.e., learning for the sake of learning). Rewards for attaining a gradually increasing standard of performance may enhance intrinsic motivation in some situations, but undercut it in others, such as when the learner starts with a high level of intrinsic motivation. Third, because the theory assumes that knowledge exists in concrete bits of information, fact and figures independent and separate of the learner, it does not provide a space for the learner to evaluate or reflect as part of the learning process. Thus, in a behaviorist learning environment, a student could confidently assume that the professor knows the answer to any question, and it can only be right or wrong. Finally, behaviorism does not easily account for change in previously established behavioral pattern in response to introduction of new information. In short, excessive reliance on behaviorism in the classroom has led to severe critiques and warnings against the risk of indoctrinating students rather than educating them (Schillo, 1997). Whereas behaviorism is not as dominant today as it was during the middle of the twentieth century among educational psychologists, it has nevertheless provided useful insights for the development of effective classroom instruction techniques (Skinner, 1968), classroom management techniques, and computer-assisted learning, which have been deeply rooted in this approach to learning (Roblyer et al., 1997).

Constructivism

The research in child development by the Russian psychologist Lev Vygotski (1896–1934), the Swiss psychologist Jean Piaget (1896–1980), and many others in the second half of the twentieth century, has provided the foundation for the modern movement in education broadly referred to here as **constructivism**. Toward the end of his life, Piaget challenged the policymakers and educational administrators of his time to rethink the goals of the schools and the educational system as a whole. He asked:

... The question is whether schools serve to train children and individuals who are capable of learning what is already known, to repeat what has been gained by prior generations, or to develop creative and innovative minds capable of inventing, discovering, starting at school and then throughout their entire lives.

(Piaget, undated.)

The constructivist view of learning emphasizes active mental processes (the very processes deemed unobservable by behaviorists and thus unworthy or scientific experimentation) and the social context in which it takes place. Rather than “acquiring”

new knowledge, the learners build their own knowledge because they naturally seek meaning. The learners bring internal motives, distinct levels of aptitudes and consciousness, past experiences, a variety of world-views, preconceptions, and even cultural biases to a learning situation. Learning occurs when one has internalized information and created their own representation of reality by making connection with prior knowledge (or skills) through both individual and social activities. Two inter-related core concepts espoused by constructivists are the **zone of proximal development** (Vygotski, 1978) and **scaffolding** (Wood et al., 1976), which have been merged in the illustration presented in Figure 1.3. The zone of proximal development is “the distance between the current developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under guidance from more competent peers or the guidance of an adult” (Vygotski, 1978). It is in the zone of proximal development that teachers must focus their attention. Scaffolding is a process through which a teacher or a more competent peer helps focus on the elements of the task that are initially beyond the reach of the learner’s capacity, but within reach with adequate support. Scaffolds are teaching and learning structures put in place to allow the learner to achieve higher level of performances on their own. However, just as scaffolds in building construction are eventually no longer needed and are removed, instructional scaffolding should eventually become unnecessary as the newly added knowledge or skills have been completely internalized (i.e., have become part of an expanded mental structure or set of skills). Instructional scaffolding is thus the temporary means by which experts (defined here as individuals with higher performance skills than the learner) assist a novice or an apprentice on the path to more experience and greater expertise. For the most part, constructivists see teaching and learning as a highly contextualized process mediated through social interactions.

Thus, constructivism has helped teachers understand that classroom design and implementation should account for diversity in the learners, should rely on a variety of teaching methods and should include formative assessments techniques (CATs) as ongoing processes. Numerous CATs have been tested and are now available (Angelo and Cross, 1993; FLAG, 2012). Furthermore, in a classroom designed according to constructivist principles, the instructor’s main role has shifted from a mode of delivery of course content to that of a guide, a facilitator, or a learning coach. However, it would be a misconception to believe that constructivism demands that instructors never “tell” students nor provide “formal” instruction for fear of interfering with their knowledge construction.

Constructivism assumes that all knowledge builds on the learner’s previous knowledge, regardless of how one is taught. Thus, even listening to a lecture may involve active attempts to construct new knowledge. However, a more typical constructivist classroom has teams of students working together to form a “knowledge-building” (i.e., learning) community. Such classroom environment could be characterized, “among other things,” by activities such as in-class group quiz and problem sets, or out-of-class inquiry-based team projects followed by discussions, written reports, or oral presentations as primary modes of sense-making.

Thus, constructivists would agree that student learning is the focal objective of any instruction. Activities should be student-level appropriate. Constructivist instructors have the ability to perceive students’ conceptions of material from the students’ perspective. They will see students’ “mistakes” as reflecting a particular stage of development. Thus, constructivist instructors do not fall victims to the “expert blind spot” (i.e., the inability to remember what it was like to be a novice learner of the material at-hand; Nathan and Petrosino, 2003). In addition, constructivist instructors recognize that substantial learning occurs in periods of conflict, surprise, over time, and through social interaction (Biggs, 1996; Wood, 1995).

Transferable and life-long learning skills and aptitudes

As illustrated in Figure 1.1, half of one’s lifespan is spent in professional settings during which continuing education is becoming increasingly part of the expectation. As indicated earlier, effective teaching and learning in the college classroom should be informed also by the literature on adult and continuing education. In other words, learning at the university should not only be about what is measurable in the short term or what can be done with temporary assistance of a knowledgeable instructor, but should also be about learning to be an adaptable life-long learner, which comes in part with the ability to reflect and exercise metacognition. Wingate (2007) described “learning to learn” in college as first, understanding “learning” and becoming an independent learner, and second, understanding “knowledge” and becoming competent in constructing knowledge within the discipline (Table 1.3). In addition to delivering knowledge, higher education curricula and classrooms should be designed to prepare students with a set of skills and experiences that reflect certain habits of the mind (Wattiaux, 2009). Furthermore, the curricula and the classroom should emphasize transferable skills and aptitudes that are relevant in most professional situations, such as oral and written communication, problem solving, creative thinking, interpersonal skills (e.g., respect of diverse views), leadership skills (e.g., self-motivation, decisiveness, risk-taking), and personal aptitudes (e.g., integrity, reliability, diligence) among many others (Assiter, 1995). Transferable and life-long learning skills are important not only as a means for university graduates to stay current in their professional fields, but also for personal enrichment and enhancement of quality of adult lives (Dunlap and Grabinger, 2003). Authors have grouped life-long learning skills in three categories:

1. Capacity for “self-directed” learning (e.g., identify problems, establish goals, develop an action plan, identify critical resources, capture and use relevant information),
2. Capacity for metacognitive awareness (e.g., the ability to reflect, to strategize, and to self-assess),
3. Capacity toward long-term results (risk taking, intellectual curiosity, seeking deep understanding, gaining intrinsic motivation).

Table 1.3 Components of “Learning to Learn” in higher education as (a) understanding “learning” and (b) understanding “knowledge” of a discipline (reproduced with permission from Wingate, U., 2007. A framework to transition: supporting “learning to learn” in higher education. *Higher Education Quarterly* 61(3):391–405).

(a) Becoming competent in independent learning	(b) Becoming competent in knowledge construction
1. Gaining awareness of conceptions of learning and knowledge in the discipline	
2. Assessing one’s current abilities as learner	2. Approaching information (lectures, texts) in a focused and critical manner
3. Setting short-term and long-term goals and targets	3. Evaluating existing knowledge
4. Planning action for reaching targets	4. Synthesizing different sources into a coherent argument
5. Monitoring progress in reaching targets	5. Expressing own voice.
6. Evaluating progress/achievements	

Understanding teaching

Research in teaching

In contrast to research on the learner and the learning, the research on the teacher and the teaching has been more limited and has a shorter history, especially in institutions of higher education. Over the course of the twentieth century, higher education has not benefited to the same extent as K12 from the type of research in which a community of educational scientists uses their training and expertise to study teaching effectiveness. Furthermore, with the availability of students’ performance on standardized tests as a metric of student learning, researchers have revealed what effective K12 teachers do in their classrooms and the extent of their influence on students’ performance (Stronge et al., 2011). In comparison, the quality of undergraduate education in institutions of higher education has suffered for the lack of attention, especially as research accomplishments prevailed as the principal means of recognition and prestige for both individual scientists and their institutions throughout the second half of the twentieth century (Serow, 2000). However, about 20 years ago, the Carnegie foundation for the advancement of teaching released the Boyer’s report: “Scholarship Reconsidered: Priorities of the Professoriate” (Boyer, 1990) challenging universities to expand the definition of scholarship beyond the realm of scientific discoveries. The report identified three other types of scholarships that had been core to the professional identity of university professors in the United States since the inception of the land grant system, namely, the **scholarship of teaching**, the **scholarship of outreach**, and the **scholarship of integration**. Since then, at least two distinct areas of research to enhance the quality of teaching in higher education have emerged. The first area focused on changing the institution whereas the second focused on changing the classroom.

Changing the institutional paradigm

Throughout the second half of the twentieth century there were few institutional concerns about the quality of undergraduate

education. As institutions were competing to hire the most promising scientists, the assumption that good researchers were good teachers was – and unfortunately, for the most part remains – pervasive. The presence of a disciplinary expert in the classroom was deemed a sufficient guarantee of teaching quality. However, since Boyer's report (Boyer, 1990), research has been conducted to guide and document institutional reform and there is now an increasing body of literature on institutional structure and organization to sustain and advance the educational mission of the university and the instructors within (Dooris, 2002). The following examples illustrate the issues that have been documented through this type of research:

- The relationship between research and teaching (Marsh and Hattie, 2002), and the belief system about teaching at research universities (Kane et al., 2002; Wright, 2005);
- The financial compensation disparity between teaching and research (Fairweather, 2005);
- The faculty evaluation and accountability system (Arreola, 2000);
- The reward system through promotion and tenure (Keele, 2008) and whether multiple forms of scholarship has been increasingly rewarded or not in the last decade (O'Meara, 2005; 2006);
- The current systems of expectations and standards of faculty performances in research universities (Colbeck, 2002; Hardré and Cox, 2009).

Among current concerns is an institutional failure to support adequate teaching-related training for graduate students aspiring to a professional career in academia. At the turn of the twenty-first century, roughly 70% of instructors in the 3200 institutions offering four-year degrees in the United States had received their Ph.D. from one of the roughly 150 "Research and Doctoral" (R&D) institutions (Bob Mathieu, personal communication). Most Ph.D. programs at R&D institutions do not encourage, let alone require, training in undergraduate education and, therefore, most of the current instructors in the United States' higher educational system were utterly unprepared to engage undergraduate students in a semester-long course as they began their academic career. Although some may argue otherwise, there are some signs of change as an increasing number of R&D institutions have begun to offer their graduate students and post-doctoral trainees opportunities to gain knowledge, skills, and meaningful experiences related to undergraduate education (CIRTL, 2012). Furthermore, teaching experience and teaching philosophy have increasingly become points of differentiation in the screening and selection of candidates for faculty positions.

Changing the classroom paradigm

In parallel to institutional reform that began in the 1990s; another important movement emerged as committed educators pointed to a necessary paradigm shift from teaching to learning in the classroom (Barr and Tagg, 1995; Bass, 1999; 2012; Shulman, 1999). Focusing on student learning outcomes rather than the instructor teaching performance has led to what is known as the Scholarship of Teaching and Learning (SoTL). Committed teachers have taken upon themselves to conduct "classroom research" as a way to improve the quality of teaching and learning within their own discipline (Cross and Steadman, 1996; Reagan et al., 2009). Typically, this type of research involves an institutional review board (IRB) approved data collection protocol designed to address pedagogical issues with the intent of contributing to a body of peer-reviewed literature, as illustrated in Crouch and

Mazur (2001), Wattiaux (2006), or Wattiaux and Crump (2006). As SoTL gained recognition, confusions arose for lack of a clear definition and differentiation from "good" teaching or "excellent" teaching. Fortunately, Kreber (2002) outlined the distinction among excellence in teaching, expertise in teaching, and the SoTL. In addition, the same author helped bring some consensus to delineate the defining features of SoTL, which accordingly is an activity that, in the context of promoting student learning, meets a series of criteria. For example, it requires high levels of discipline-related expertise, it should break new ground, be replicable, peer-reviewed, and provide significant or impactful insights that can be elaborated upon by others (Kreber 2003).

Although Asmar (2004) described successful attempts to engage the faculty of a research-intensive university to improve their teaching practices, SoTL has met with resistance for a number of reasons. Our current Ph.D. programs rarely engage graduate students in issues related to undergraduate teaching and learning. A lack of knowledge and training is likely associated with a lack of confidence, interest, and motivation for SoTL as a basis to build a successful academic career. Similarly, institutional priorities and reward systems rarely foster faculty engagement in SoTL. According to Boshier (2009) low adoption of SoTL may be related also to continued confusion about the concept, the difficulty to operationalize classroom research in absence of appropriate resources (e.g., lack of expertise and financial support), the over-reliance on peer-review publications as the main criteria to measure scholarship, and the fact that SoTL fits poorly in the twenty-first century *modus operandi* of universities as businesses delivering education as a commodity to be sold. Notwithstanding the uncertain future of the SoTL in its current form, college science classroom research (the contextualized environment in which the teaching and learning is taking place) has been identified along with brain research (Taylor and Lamoreaux, 2008) and cognitive psychology (which focuses on mental processes including how people think, perceive, remember, speak, and solve problems) as the three components of trans-disciplinary research that will advance our ability to create effective university classroom in the twenty-first century (Wieman, 2012). Furthermore, it is clear that engaging in SoTL should be dependent upon one's institutional context and professional priorities. Not all STEM (science, technology, engineering, and math) scientists should be expected to become educational scientists within their classroom. However, the difference between excellence in teaching and SoTL is not entirely categorical as most features and evaluation criteria lay on continuous scales most indicative of one or the other (Wattiaux et al., 2010). For example, reflective practices (Kane et al., 2004), classroom assessment techniques (FLAG, 2012), and engagement in faculty learning communities are simple steps that may transform one's classroom overtime and place an instructor on the path towards excellence in teaching without necessarily engaging in SoTL.

Implications for classroom design in the twenty-first century

Architecture of an effective classroom

As described so far in this chapter, the implicit or explicit assumptions made about learning, the institutional context, and the inclination of an instructor to engage in teaching improvement initiatives are only some of the factors that influence the instruc-

Table 1.4 Example of an alignment scheme among instructors’ activities, students’ activities and tests to assess learning using the revised Bloom’s Taxonomy (Krathwohl, 2002) as a frame of reference.

Cognitive process dimension ¹	Examples of instructional activities (instructor)	Examples of learning activities (student)	Examples of how students demonstrate learning	Examples of how instructors assess learning
1. Remember: Ability to retrieve knowledge from long-term memory	Lecture; Tell; Show	Read; Review; List; Match	Memorize and recite; Name; Define; Recognize	True-False; Multiple choices
2. Understand: Ability to make sense of oral, written, mathematical or graphical information	Discuss (Q&A); Demonstrate; Illustrate	Give examples; Explain; Solve problems; Infer	Write a summary; Complete worksheet; Compare	Short answers; Mini-essay; Calculation; Comparison
3. Apply: Ability to carry out or use a procedure in a given situation	Train; Coach; Guide	Work on scenarios; Use a procedure	Solve real-world problems	Written report; Oral presentation
4. Analyze: Ability to break material into parts, detect connections and an overall purpose	Provide resources; Model	Compare sources of information, scenarios, or procedures	Organize information; Differentiate associations from causality	Assess a literature review; Evaluate oral answers or reasoning
5. Evaluate: Ability to make judgments based on criteria and standards	Provide resources; Facilitate	Assess; Critique; Check	Provide feedback to peers	Assess student’s ability to provide feedback to peers; Portfolio
6. Create: Ability to put elements together to form a coherent and original product	Provide resources; Collaborate	All of the above as needed	All of the above as needed	Assess the design and content of a web page or a research proposal

¹Listed here as “learning objectives”: listed in increasing order of complexity and level of abstraction (from concrete to abstract). Note that the mastery of each simpler category is assumed to be a pre-requisite to mastery of the next more complex one. Level 3 and above are usually referred to as “critical-thinking” skills.

tional design of a university classroom. Interestingly, undergraduate instructors willing to reconsider the architecture of their classroom may act at times as behaviorists (“tell me what to do!”) and at times as constructivists (“let me try this!”). The propensity toward one or the other may depend upon professional expectations and personal factors such as intrinsic motivation, level of knowledge, prior experience, prospect of reward, and the context of a particular classroom (e.g., the type of course and the intended learning outcomes).

Regardless of the context, the seven principles for good practice in undergraduate education promoted since the late 1980s (Chickering and Gamson, 1987) remain a solid foundation and a useful guide in designing an impactful undergraduate classroom. These principles are:

1. student-faculty contact,
2. cooperation among students,
3. active learning,
4. prompt feedback,
5. time on task,
6. high expectations, and
7. respect for diverse talents and ways of learning.

Since then, however, books have been written in designing effective courses and curricula (Diamond, 1998; Wiggins and McTighe, 2006). This recent literature emphasizes the importance of proper alignment among three essential components of any course syllabus: the intended learning outcomes, the teaching and learning activities, and the learning assessment (i.e., the grading scheme). It is not difficult to appreciate that this type of alignment serves both the constructivist-leaning classrooms

(Biggs, 1996) and the behaviorist-leaning ones. As designers of learning environments, instructors should make these alignments deliberately at the planning stage or as part of the revamping of a course. Table 1.4 was constructed to illustrate what instructors “do” and correspondingly what students “do” at each of the six cognitive processes recently published as a revised Bloom’s taxonomy of learning (Krathwohl, 2002). Instructional activities, learning activities, how students demonstrate learning, and how instructors assess learning should vary substantially given the intended learning outcome (remember, understand, apply, analyze, evaluate, and create). Thus, there should be a conscious effort to provide the learner with clearly stated goals, activities that are appropriate for the task, and assessment criteria that reflect the intended goals. In their book *Understanding by Design*, Wiggins and McTighe (2006) coined the phrase “backward design” to describe instructional design as a process that includes the following three sequential steps:

1. Identifying the desired learning outcomes;
2. Determining the acceptable evidences [of learning];
3. Planning the instruction and learning experience.

Although this three-step approach may be counterintuitive, it demands that instructors focus first on the “end-point” (i.e., the goal), then determine how to assess the desired knowledge or skills to be gained (e.g., create the exams, homework, or rubrics for written reports that will be used to assign grades), and finally decide on what tools to use from one’s teaching toolbox to provide students with the most appropriate learning experience (i.e., instruction). Note that the backward design is a scalable process that may be applied not only when writing the syllabus