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Academic lectures for the purpose of instruction maintain an important presence in most colleges and universities worldwide. This chapter examines the current state of the lecture and how learning sciences research can inform the most effective use of this method.

The Lecture

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> Most people tire of the lecture in ten minutes; clever people can do it in five. Sensible people never go to lectures at all.
>
> —Canadian satirist Stephen Leacock

Leacock's quote (Sherin, 1995, p. 104) notwithstanding, several years ago I attended a memorable hour-long lecture. In his acceptance speech for an award from the American Association of Physics Teachers, physicist Dean Zollman recounted a lesson he learned from his daughter, Kim, when she visited his university (Zollman, 1996).

> One day we were walking down a hallway, and Kim was looking in the rooms as a young, rather inquisitive girl does. She saw a scene which for her was very unusual—over a hundred students sitting in a room and watching one person talk. . . . She asked me the rather obvious question, "What are all those people doing?" I came up with what I thought was an excellent answer, "They're learning physics." Her response was "Do they just sit there?" (p. 114)

Zollman went on to share that

> thinking about how people might learn physics was rather new to me, but I realized immediately that this question was profound. At the age of eight or nine she knew that just sitting there was not the way that people learned—it certainly wasn't the way that she learned. (p. 114)

New Directions for Teaching and Learning, no. 128, Winter 2011 © Wiley Periodicals, Inc.
Published online in Wiley Online Library (wileyonlinelibrary.com) • DOI: 10.1002/tl.464

Zollman delivered his speech in a large hall attended by several hundred people, all of whom had substantial training in physics and experience in teaching it. No doubt that many of them, as I did, marveled at the power of this story and made mental notes to think further about this issue—how *do* our students learn when they sit in large lecture classes alongside scores of their classmates listening to one person talk? Zollman's lecture was inspiring, effective in delivering a message that I still remember, and at the time prompted further thought on an important issue in student learning.

Teachers rarely lecture under such optimal conditions. A typical fifteen-week semester might require instructors to deliver forty-five lectures to students who may have little background or interest in the subject matter. Other classes and distractions from work or co-curricular activities can further reduce the impact of learning from a lecture (Davis, 2009; Di Leonardi, 2007; Exley and Dennick, 2004; Svinicki and McKeachie, 2011).

In this chapter, I present evidence that the lecture can be an effective element of instructional practice. This chapter focuses on the lecture method, the delivery of information in an organized way to a large group of recipients by one person, and the lecture system, which includes the lecture along with specific activities involving students' active participation in learning the subject matter (McLeish, 1968).

Lecture Methods and Lecture Systems

The word "lecture" is derived from the Latin *lectare*, meaning "to read aloud." In medieval times, "a monk at a *lectern* would read out a book and the scholars would copy it down word for word" (Exley and Dennick, 2004, p. 3). It is astounding that the scene today in many college lecture halls is not all that much different. Broadwell (1980) provided a clue to the lecture method's longevity: "[I]t is virtually limitless in application, either to situation, subject matter or student age and learning ability" (p. xii).

Bligh (2000) conducted an extensive meta-review of the lecture literature in which he reviewed over one hundred studies comparing the lecture against other teaching methods (e.g., discussion, independent reading, inquiry projects). His main criterion for comparison was acquisition of information by students. The evidence supported Bligh's assertion that "the lecture is effective as any other method for transmitting information but not more effective" (p. 4).

Bligh's view of the role of students in lecture matched what Kim Zollman saw as she passed by the lecture hall: "[T]hey sit listening; their activity usually consists of selecting information from what is said, possibly translating it into their own words or some form of shorthand, and then writing it down" (Bligh, 2000, p. 9). However, because the lecture continues to be the primary method of instruction in introductory college courses, it is important that we look at ways in which modern lecture classrooms can become more effective environments for engaging students in learning.

Zollman's success in delivering a memorable lecture can possibly be explained by the fact that he presented relevant content for a motivated audience in an appropriate setting. In his talk, Zollman (1990) described how his daughter's comment led him to adapt the learning cycle (Karplus, 1980) based on Piagetian principles, to restructure a large-enrollment science course. The learning cycle is a pedagogical approach that promotes active inquiry and critical thinking. Each topical area is structured to have an exploration, a concept introduction, and an application phase. Zollman conducted the exploration and application phases outside of class in an activity center. Weekly lectures and assessments tied together the phases of the learning cycle.

Zollman (1990) compared student learning in two sections of the class: one taught by conventional lecture and one by the learning cycle method. He analyzed the final examination results by dividing the exam scores into four partial scores representing the major topics and by analyzing the exam in terms of the type of cognitive skills needed to answer the various questions. For all topic categories, the learning cycle group scored higher than the traditional lecture group. When analyzed for type of cognitive skills needed, the learning cycle group scored higher on conceptual explanations and calculations but lower on recall questions. This course model has continued to support strong conceptual learning in students even when multiple instructors have taught it over a period of twenty years. (D. A. Zollman, personal communication, October 5, 2010).

Applying Learning Sciences Research

Research from the learning sciences directly supports Zollman's learning cycle approach to the lecture system. In a National Research Council (NRC) review of evidence from scientific literatures on cognition, learning, development, culture, and the brain regarding human learning, Bransford, Brown, and Cocking (2000) recommended that teachers design their courses to be learner centered, knowledge centered, assessment centered, and community centered. By making meaningful connections between the content of lecture and student activities outside the classroom, Zollman built a robust lecture system.

According to Bransford and others (2000), a learner-centered environment design is consistent with evidence showing that learners use their current knowledge and beliefs to interpret new information. A knowledge-centered approach to instruction emphasizes that teachers should focus on developing students' abilities to think and solve problems with knowledge that is accessible and applied appropriately. Research also indicates that feedback is fundamental to learning but is often absent in classrooms (e.g., Pellegrino, Chudowski, and Glaser, 2001). In an assessment-centered environment, students should be able to revise and improve the quality of their thinking and understanding. Finally, the NRC report urged that learning environments should foster a sense of community norms where students, teachers, and other participants value learning and high standards (see also Halpern and Hakel, 2003).

Some Interesting Variations on the Traditional Lecture

Although the NRC recommendations are applicable across disciplines, their implementation in the sciences has given rise to some interesting course designs that represent both small and large variations on the lecture method. For example, Mazur (1997) described his implementation of peer instruction (PI), an interactive student engagement strategy that utilizes a structured questioning process in enhancing student learning. Carefully chosen questions presented during lecture give students the opportunity to discover and correct their misunderstandings of the material and, in the process, learn the key ideas of physics from one another. Fagen, Crouch, and Mazur (2002) reported increased student mastery of both conceptual reasoning and quantitative problem solving using PI in teaching physics. Gains in student understanding were greatest when they used PI in combination with other strategies, such as reading incentives that connected lecture content to students' online responses to preassigned readings. The authors also reported nationwide learning gains from courses taught by other instructors who implemented PI.

Using a different approach, Udovic and others (2002) described a redesigned introductory biology course based on the "workshop" approach pioneered by Laws (1991) and Wilson (1994). In this course, the authors replaced almost all lecturing with student group problem solving and other projects. The traditionally taught control course met weekly for three regular fifty-minute lectures and one ninety-minute laboratory session. Over two years with the same instructor, the evidence showed that the inquiry-learning activities in the workshop course were more effective than the traditional course at helping students construct a robust understanding of fundamental concepts and an improved ability to use concepts to solve unfamiliar problems.

Likewise, Beichner and others (2007), the developers of Student-Centered Activities for Large Enrollment Undergraduate Programs (SCALE-UP), demonstrated significant learning gains on standard conceptual inventories of student learning in physics that compared favorably against national samples (Hake, 1998). The original implementation of this model placed ninety-nine students at eleven round tables working in groups of three on cognitively engaging tasks. The room design facilitated learner-centered teaching, and the curriculum materials facilitated knowledge-centered and assessment-centered teaching. Groups of students engaged in cognitively meaningful tasks formed a community of learners. Two aspects of this study are particularly noteworthy. First, students in the upper third of their class had the largest gains in learning, which demonstrated that an active learning approach was most beneficial for the highest achievers. Second, the failure rate for all students in the SCALE-UP class was one-third that of traditional lecture courses. Women and ethnic minorities were up to six times more likely to pass the reformed course than the traditional one. The SCALE-UP model has since been adopted for introductory science and engineering courses on many campuses with class sizes ranging from about fifty to over one hundred (Beichner and others, 2007).

In yet another study of interactive lecture systems, Knight and Wood (2005) performed a controlled study in an upper-division biology course in which approximately 30 to 40 percent of lecturing during class time was substituted with more engaging student-centered activities. Normalized learning gains (which allowed for comparison of students with different levels of incoming knowledge) calculated from pretest and posttest scores administered each semester indicated that the interactive approach was 33 percent superior to the traditional lecture method in boosting student achievement. Like Beichner and others (2007), Knight and Wood reported that students with grades of A or B had higher learning gains in the interactive course; C students achieved the same learning gain range in both types of courses.

Using clicker technology (Bruff, 2009; Duncan, 2005), Mayer and others (2009) examined whether the technique of "questioning" could be used successfully to foster generative learning in a large lecture general psychology class. The instructor asked two to four multiple-choice questions each class period that mirrored the type of questions students might see on the final exam. Mayer and coauthors investigated students' exam performance across three different sections of the course: a traditional lecture-based section with no in-class questions, a traditional lecture-based section using questions delivered and collected on paper, and a traditional lecture-based section where question responses were collected through clickers. There was no significant difference in the demographics or prior scholastic ability of the students across groups, and no other modifications were made to the course content. The same instructor taught the material for three consecutive years, which enabled the authors to examine whether students' cognitive skills could be assisted solely by a new technology.

The clicker treatment produced a gain of approximately one-third of a grade point over the other two conditions; the control conditions did not produce results that differed significantly from each other. This finding indicated that the questioning technique alone, when integrated into lecture (implemented on paper and somewhat disruptive to the class), was not so effective as the seamless integration of clicker-enabled questioning.

Student Attitudes Toward Lectures

Bligh (2000) found little compelling evidence that traditional lectures were effective in changing student attitudes toward the subject matter. Handelsman and others (2004) also pointed up that large lecture courses often do not contribute to fostering students' scientific curiosity, analytic thinking, and reasoning, key skills for future scientists. Redish, Saul, and Steinberg (1998) described results from the Maryland Physics Expectations Survey (MPEX), an instrument that probes student attitudes, beliefs, and assumptions about physics. Data from pre- and postinstruction surveys of 1,500 students enrolled at six universities indicated that scores often deteriorated by 5 to 10 percent after one semester of lecture-based introductory physics, whether the course had been modified to improve conceptual learning or not.

Redish and Hammer (2009) presented evidence of a promising approach that reversed this trend by focusing on lecture content, student engagement, and helping students learn how to learn science. They implemented three procedures that helped students modify their initial views on the nature of scientific knowledge and how to build physical intuition.

1. Explicit epistemological discussions tied a particular set of points presented by the instructor to a scientific process such as "sense making."
2. Modified PI (with clickers) included discussion with students about the kinds of thinking that could lead to their choosing incorrect responses to multiple-choice questions.
3. An adapted set of interactive lecture demonstration materials (Thornton and Sokoloff, 1998) emphasized the valid content of students' intuition and helped refine it.

In a follow-up study, Redish and Hammer (2009) evaluated student conceptual learning over multiple semesters and instructors and recorded normalized learning gains in the range shown by the stronger active engagement classes reported by Hake (1998). Student attitudes also shifted significantly toward experts' views of physics. These authors also reported that although there was initial resistance from students who had been successful in traditional courses, even the most vocal, accomplished students demonstrated understanding of the value of the instructors' epistemological approach at the conclusion of the semester.

Conclusions

Although the lecture method likely will continue to be a common method of teaching in higher education, the nature of the lecture is evolving from static formats in which students sit passively listening to the teacher speak nonstop for fifty minutes to more dynamic and interactive sessions that require active student involvement in learning the subject matter. Miller, Pfund, Pribbenow, and Handelsman (2008) described an exciting interactive lecture technique for teaching biology in which the majority of class time is devoted to active learning activities delivered in units created by graduate students and postdoctoral fellows. Relative to students in control classes, students taught using this method showed gains in knowledge of specific subject areas, enhanced success in solving complex problems, and long-term retention of knowledge they learned months earlier. Thus, although there is no doubt that the lecture method remains an efficient way to deliver large amounts of information to large numbers of students, it is now apparent, based on empirical research on human learning, that lecture systems are currently evolving that enhance student engagement in the learning process and improve performance in most areas of student assessment.

Few teachers are able to deliver memorable, indeed inspirational, lectures like Zollman. The good news, however, is that all teachers can develop effective lecture-based systems, grounded in evidence-based practices, that stimulate and reinforce student learning and understanding in both the short and long term.

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