LEARNING WITH LECTURES

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A lecture can have a range of possible purposes: to entertain, to inform, to persuade, and so on. This document focuses on one particular purpose: to learn. Notice an important shift in this focus: from the speaker and the speech to the students and their understanding. It is by changing perspectives in this way that a speaker can craft a lecture that will facilitate the task of the student, that will make it easier for him or her to learn.

In taking the perspective of the student in this document, we are going to examine some important research findings about how students learn and then derive some implications for how lectures can be structured and delivered so as to help students understand.

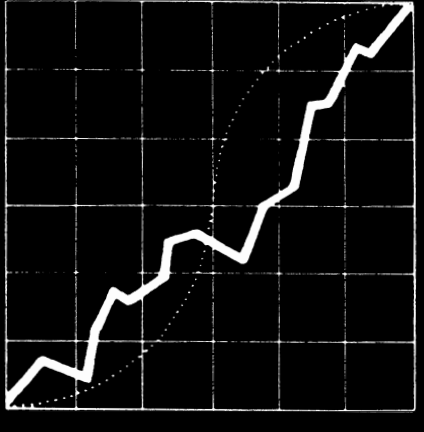
The intended audience of this memo consists of faculty members and teaching assistants who teach introductory courses within the constraints of the large lecture hall. Those who are fortunate enough to teach smaller classes are encouraged to take advantage of the situation to have students do more of the talking (and thinking). Extensive student participation is frequently precluded by large lectures. Nonetheless, there are ways that lectures can be conducted to increase student engagement and support student understanding, and that is the focus of this memo.

Factors that Affect Learning

Learning is a process whereby students actively construct their understanding of a topic by integrating information they get from their environment with knowledge that they already have in memory. Consequently, two factors that affect learning are prior knowledge and new information. As a lecturer, you have the most control over the new information that you provide—its content, organization, pacing, etc. To facilitate learning, your task is to present this new information in a way that allows students to connect it with their prior knowledge and extend their understanding.

Learning Depends on Prior Knowledge

The understanding and value that students already have for a topic is sometimes referred to as "prior knowledge." The content of a student's prior knowledge, the way it is organized, their goals and their interests all play a crucial role in their understanding of new information. The more similar prior knowledge is in content and organization to new information, the more understandable the new information will be and the more it will extend the student's existing knowledge. As a lecturer, you must guess or find out what your students already know and adjust your presentation to their prior knowledge.



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A major difficulty in doing this, however, is that prior knowledge varies greatly among students. The prior knowledge of some students, particularly graduate students and seniors majoring in the discipline, may be quite advanced and similar in important ways to that of the instructor. They may know about many important concepts in the discipline and understand how these concepts are related. They may also understand important principles that underlie and integrate the discipline. For this reason, you may find lecturing to advanced students and colleagues relatively easy and more enjoyable than lecturing in an introductory course.

The knowledge of introductory students, on the other hand, is much different. This knowledge not only differs greatly from that of the instructor, it frequently differs among introductory students. The knowledge of some introductory students will be incomplete, fragmented, and unconnected. Some students may know one concept but have no knowledge of another; other students may be familiar with both concepts but not the relationship between them. These students may know a number of facts and formulae but not know how to apply them. They are likely to lack an understanding of important principles that underlie and integrate the topic.

For students with little prior knowledge, the task of learning is to build incrementally on their incomplete understanding by adding new concepts, elaborating on existing ones, and connecting concepts to each other. For these students, your task as lecturer is to continually make references between the current topic and what they already know and what you have discussed previously. You may even foreshadow relationships between what you are currently talking about and what you will discuss in future lectures.

Other introductory students, even very capable ones, may come to a course with a rather extended, elaborate, *but incorrect* understanding of the topic. The understanding of these students may form a consistent "theory," but this theory is inaccurate compared to that held by experts in the field. For example, many students in introductory physics will come to class with a misconception, based on their personal experience, that an object will continue to move only as long as acted upon. Also, in our study of college students' understanding of chemical equilibrium, we found that some students know that when a chemical system is stressed (i.e., concentration of a reagent is increased, temperature is increased, etc.), the equilibrium of the system will shift, but they believe that when the new equilibrium is reached, the reaction comes to a stop. For these students, the task of learning is different and more complex. Rather than adding to their understanding, they must restructure and reorganize it. In effect, they must unlearn some of what they already know—this is much more difficult. Without doing this, students will merely reinterpret everything they hear to fit with and reinforce their current, inaccurate understanding. Your task as lecturer is to gently confront these students with their misconceptions and help them reorganize their understanding.

Learning Depends on New Information

Clearly, learning not only depends on prior knowledge but on new information. It is the new information that you provide which allows learners to elaborate, interconnect, and even restructure their understanding. Unfortunately, the task is not as simple as giving students the information that you want them to understand. There are certain requirements and limits to learning that you must accommodate.

For example, there is only so much information that a learner can handle at a given time. What any of us can actively hold in memory at any one time is limited to about five ideas, or "chunks" of information. These chunks include both new information and the prior knowledge that needs to be activated in order to understand the new information. The size of a chunk is subjective; what is five independent ideas for a person new to a topic may be one interrelated chunk for someone who knows the topic well; again, prior knowledge comes into play. Perhaps this is an unnecessary quantification for our purposes, but the point is that for introductory courses where students are not likely to have incorporated many ideas into higher order concepts and principles, the number of ideas that you include in a lecture should be limited.

A second, related consideration is the amount of time needed to fix an idea into permanent memory. We don't remember everything that we think about, let alone hear. Rather, we remember those ideas better that we spend more time thinking about and interconnecting with our current understanding. Thus, the advantage of limiting the number of topics that you discuss is that you can spend more time talking about them, and students can spend more time thinking about them. Achieving the proper pace for your lecture is probably the hardest thing you have to do. Finding the right balance comes with experience and with a growing understanding of what your students already know and how quickly they learn. Asking them questions will allow you to speed up if they understand and slow down or repeat things if they are having difficulty.

Lectures That Support Learning

How can you give a lecture that can make it easier for students to learn from it? First of all, lectures have an inherent flaw. To "listen" to a lecture, a person does not have to be actively engaged in understanding it, and the lecture progresses whether or not understanding is achieved. Yet, as mentioned above, *learning* with a lecture does require active involvement. Your goal as lecturer is to get students engaged in understanding what you are saying. We will look at techniques that facilitate each of these components: engagement and understanding.

Facilitating Engagement

There are a number of speaking techniques, such as the use of humor and variation in intonation, that you can use to capture and maintain your students' attention. While these techniques are useful, we are more concerned here with a deeper cognitive and even emotional engagement in the topic. We want students committed to and actively involved in constructing their understanding while listening to your lecture. There are several ways of doing this.

Ask questions. The use of questions is very important. Questions can do two things: they can give you a better idea of exactly what your students already know, and they can get students more involved in learning. Questions can turn your one-way lecture into a mental, if not actual, dialog that requires students to think about what you have said. Responding to questions is exactly the kind of mental processing that is needed for students to connect new information with prior knowledge. While complex questions are sometimes useful, even questions requiring simple yes or no responses can get students to think about what you are saying. When you ask a question, pause and wait for a response. If one is not volunteered, choose a student. If there is more than one volunteer, don't choose the first one. Students will quickly learn that you expect them to answer. If even this level of question answering takes too much time, have students write down a response. Have them write a "one minute" paper.

Provide for student participation. If you can afford the time, another way to get students involved is to have them interact with each other during class. This will get many more people involved in talking, thinking, and learning than you can when you are interacting with one student at a time. You can turn even large lecture halls into discussion sessions by having students discuss a question with the people next to them. Keep these discussions focused and relatively brief. Ask questions that require a specific answer. If more than one answer is acceptable, have the students decide on the best one and give the reasons for their choice. Have them write down their answers, even if they are not turned in. Have several groups report out their answers and debate conflicting ones.

Make lectures challenging. While you do not want the lectures to be so advanced, relative to prior knowledge, that students will not understand them, you do not want to "dummy them down" either. If the lecture is too redundant or simple, students' attention will wander. You can make the lecture challenging by keeping within a window of engagement where the topic is comprehensible but just beyond their current understanding.

Make lectures motivating. When we lecture we are asking students to make a significant commitment to attend to, engage in, and learn from what we say. This kind of intense involvement happens too rarely, but when it does it is rewarding for both students and the lecturer. There are things that you can do in lecture to increase the likelihood that it will happen. As with prior knowledge, students come to class with a range of motivations; the trick is to tap into these. Some students are intrinsically interested in the course and its topics. While these students need the least assistance with their motivation, they can benefit from seeing how the topic or the field is intrinsically motivating to you. Let people know what you find interesting about the topic and why you chose to study your discipline or specialization. Other students are interested in the role that the course will play in their future careers. Show how the topic relates to and can be used in real world situations. Finally, even students who are taking the course only because it is required are likely to be intrinsically interested in some other specialization or discipline. Show how your topic relates to or can be understood from other disciplinary perspectives.

Facilitating Understanding

Use examples and analogies. Give concrete examples of abstract principles. Again, stories and examples from the real world will allow students to connect what you are saying to their prior knowledge. But, to be effective you must use examples from the *world of the student*; they may not understand examples from your world of experience if it is not similar to theirs. When you use an example, tell students why you selected it and why this one illustrates your point when others do not. Sometimes, the idea may be so abstract or the topic so unfamiliar to the students that you cannot come up with a direct example from their experience. In these cases, an analogy may be useful. Pick a more common

experience to serve as an analog that parallels the idea or principle that you are talking about in an important way. Be sure to tell the students how the analog is like the target idea or principle. It is equally important to tell them how it is different. Students can frequently learn the wrong thing from analogs if they perceive a connection that is different from the one you intended.

Think out loud. When you work through an example problem on the board, "think out loud;" make your private reasoning public. Much of what comes automatically to you and goes unstated needs to be made explicit for students. You want students to learn not only what you know but how you think. Don't just tell them what you are doing, but why you are doing it. When you take a short cut, that's fine, but make it explicit and tell them why it works and when it doesn't.

Give feedback. When students answer your questions, let them know if they are right or wrong. Often a "right" or "yes" response is all that is needed for an answer that is correct. Sometimes, you may want to expand on the student's answer to explain why it is correct. However, when a student gives an incorrect or partially correct answer, a more extended response is crucial. Indeed, this may be one of those important moments when the next thing you do or say can make a distinct difference between a student learning or not. If a student gives a partially correct response, do not go on to another student. Affirm the correct part of the answer and give the student a clue or a second question that leads him or her to think through the correct answer.

Your response to an answer that is wrong may be particularly critical. These students may be ones that have misconceptions that need particular attention. First of all, tell them their answer is wrong without implying personal criticism. These misconceptions are frequently based on personal experience, so have the student give an example where his or her answer holds. Then give a counter example where the answer does not hold. Explain why the given answer was wrong and the correct answer is right, making references to the examples. Have the student come in and see you if additional discussion is necessary.

Use multiple ways of expressing ideas. Ideas and concepts can be expressed in a variety of ways; you can describe them, show photographs, give tables of numbers, formulae, graphs, and so on. Using multiple forms of expression is a good idea. It is a particularly good way of saying the same thing without appearing to be redundant. Also, students may be more experienced with or better understand one form of expression over another. They can use their skills in one form to help them understand information presented in another form. But more importantly, each form says something different from the others. If students can come to understand and express the concept in multiple forms, they understand it better. This process is facilitated if you take the time to specify the correspondence of important information across forms of representation: how a graph is shaped in a particular way by a function, the way in which a particular diagram expresses a concept as it is verbally stated, and so on.

Help students take notes. Student notes are important because they represent the students' understanding of what you have said and they provide a record that students can review subsequently. There are ways that you can help them take notes that will further their understanding. For example, you could supply students with an outline of your lecture that states the key points that you are want them to remember. It is important, however, that your notes allow students to make their own comments, elaborations, diagrams, etc. Writing notes is actually another way students can be engaged in your lecture. So the handout should leave space for their writing, and you can prompt them to make additions, complete diagrams, and answer questions.

Juggling all of these demands can be a real challenge for a lecturer, but the more you can meet the challenge, the more students will benefit from and enjoy your lectures.

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