ConocoPhillips Lecture: An introduction to Active Learning for Busy Skeptics

Let me start by saying what an honor it is for me to be here today. I have fond memories of seeing the ConocoPhillips pamphlet show up in my mailbox as a young faculty member. I'm only sorry that you don't send hard mailings anymore, since getting to see my headshot on one of those pamphlets in my own mailbox would be the most concrete sign yet that I've made it as an academic!

I imagine that I've been invited here because of my educational research and faculty development efforts. While much of that research is highly specialized, I think my greatest impact has come through my work making active learning accessible and attractive to engineering faculty. With that in mind, I'm going to focus today's talk on an introduction to active learning for busy skeptics. That is, I want to pitch the presentation to engineering faculty who are intrigued enough to consider adopting active learning, but are at the point where they're wondering whether they really have the time and whether it's really worth the effort.

Let's start by defining what active learning is, since "active learning" is a buzz word in higher education and it's not always clear what people are talking about when they use this term. Active learning is anything that you have your students do in class that gets them to actively engage with the material you're trying to teach, as long as that "thing" isn't listening to you and taking notes. There are only those two criteria – (1) students must be doing something other than listening to the instructor and taking notes and (2) that activity must engage students in the material being taught. That's a pretty broad definition and as a result there will be any number of things that qualify as active learning. Figure 1 below is one representation of the active learning continuum.

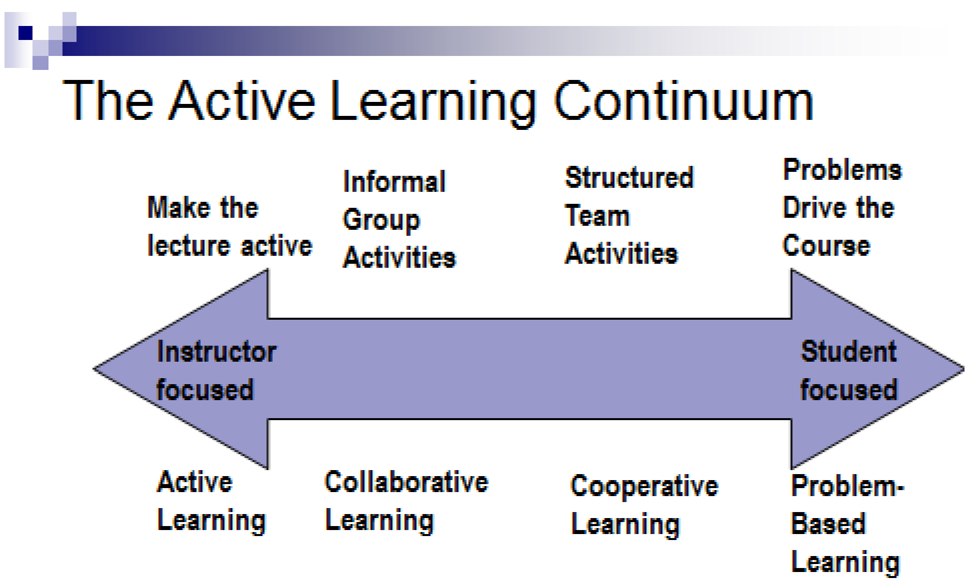


Figure 1. The Active learning Continuum

As you can see from the figure, active learning spans a number of approaches. On the left side of the spectrum is "simple" active learning. This approach is primarily instructor focused, meaning that the spotlight is most often on the instructor. In this approach, the instructor spends most of his/her time doing what I'm doing right now – lecturing. But every so often, maybe 2 or 3 times over the course of a 1 hour lecture, the instructor will stop lecturing and ask the students to do some activity that gets them to engage with the material in a different way. This type of active learning is only a minor variation on what goes on in most engineering classrooms today. If you stuck your head into a class being taught using simple active learning, 9 times out of 10 you wouldn't notice anything unusual happening.

At the other end of the spectrum are more radical types of active learning such as problem-based learning. These approaches are a large departure from traditional instruction. This also happens to be my personal favorite way to teach a course. These more radical approaches are very student-focused, meaning that the spotlight is most often on the students and most of the energy comes from the students in class rather than the instructor. If you stuck your head into a class taught using problem-based learning, you would almost never see the instructor lecturing from the front of the room. Instead, what you'd most likely see is the instructor walking around and talking to small groups of students as they work on realistic, open-ended problems. In that sense, this approach is quite different from a traditional classroom.

The take away from Figure 1 is not "The more radical you are, the better." or "The more student focused your instruction is, the better teacher you are." Instead the take away should be that active learning comes in a variety of flavors. Chances are, there is a flavor that suits you, your personality, your style, your students and your instructional goals. People like me who work with faculty to help them adopt active learning techniques are most interested in helping them find the flavor of active learning that is right for them.

Once you see that there are a variety of active learning techniques, it's natural to ask, "Which one is best?" But while that's a natural question, it's also a naïve one. Asking which type of active learning is best is like asking, "What's better, a hammer or a screwdriver?" The answer, of course, is that it depends on what you're trying to do. Similarly, the best type of active learning for you depends on a number of factors, including your goals, your experience level and the students that you're teaching. Some approaches are a natural fit for certain outcomes. For example, if you're trying to develop students' ability to work in teams, cooperative learning is worth considering because this approach gives students the guidance, practice and feedback that they need to develop those skills. Similarly, problem-based learning is a natural pedagogy for helping to develop students' ability to solve realistic, open-ended problems. Faculty simply need to be aware of these tools so that they can pick the right tool for the right job.

One natural question to ask your self is, "Why bother?" After all most of us went through traditional programs where the instructor lectured and we seem to have learned something. Why change? The short answer is "data." We simply know more about the conditions that promote learning than was commonly known by engineering faculty 30 years ago. One of the things we know, for example, is that people in our classes (including people in this audience) have an attention span of about 10 to 15 minutes. That is, after about 15 minutes you take "mental vacations". You're looking at me and seem to be paying attention, but your mind is somewhere else – on that proposal you're writing or on what you're having for dinner. After a short mental vacation, you come back and visit with me again - but in just a few minutes you'll be off again. As a result, people in lectures retain very little of what is taught after the first few minutes of a traditional lecture. One of our challenges as instructors is to grapple with the fact that our audience has an attention span of 15 minutes but we teach in much longer blocks. We can't change the way that the human brain works, so we need to adjust how we teach to deal with this reality.

Of course, there are a lot of things that a speaker can do. One of the simplest is to lecture in short segments of about 10 to 15 minutes and to intersperse these mini-lectures with short activities. This is probably the simplest way to incorporate active learning into your teaching. The natural question is, "Does this work?" Does simply breaking up the lectures actually result in more learning? Some data from one research study examining this question is shown in the table below.

Effectiveness of Short Activities

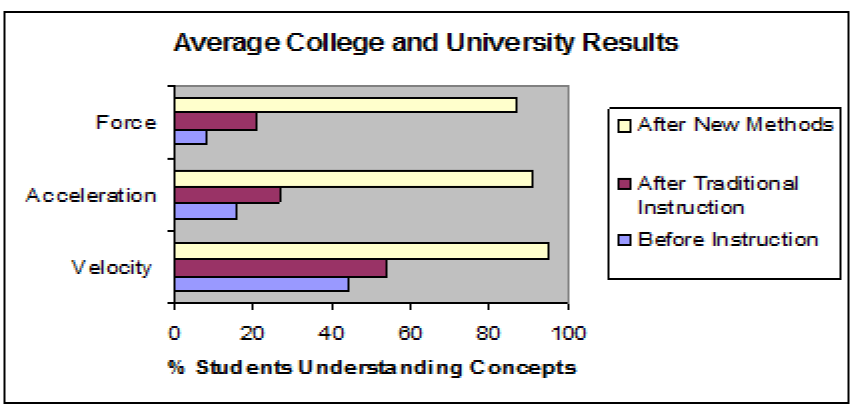
	With Pause	Without Pause
Short term recall	108 correct facts recalled after lecture	80 correct facts recalled after lecture
Long term recall	Average exam score = 84.9	Average exam score = 76.7

I chose this particular study because the intervention was so simple. In this study all the instructor did was pause for 90 seconds twice during the 1-hour period. In those 90 seconds the instructor told everyone to look at their notes and ask a neighbor if they found anything unclear in those notes. The instructor didn't call on the students or interact with them in any way beyond that. The researchers then examined the effectiveness of that intervention in two ways. For short term recall, the researchers asked the students to recall everything they could from lecture. The researchers then counted the number of correct things students could recall in both situations. When the instructor paused, students could remember 108 facts on average and when the instructor lectured straight through class, students could on average remember only 80 correct items. The researchers also assessed long term effectiveness by examining exam scores. When the instructor paused the average was about 85, compared to when they lectured straight through where the average was about 77.

The take away from studies like this is that "Less is more." That is, faculty members often feel that they need to lecture every second because they want students to walk away with more knowledge. Anyone who has lectured for more than a week knows that students don't learn everything that we say, but many instructors figure "If students only learn half of what I say and I say twice as much, they'll learn more." Unfortunately, it just doesn't work that way. When instructors ask, "What can I do to help my students actually learn more?" as opposed to the much less valuable question, "How much can I cover?" what they find is that lecturing less generally results in more learning. Obviously, that's what really matters.

One of the key elements of active learning is student engagement. Of course we want our students to be engaged and it wouldn't be surprising if someone told you that engaged students learn more. Even so, the magnitude of the improved learning found with some active learning techniques is truly impressive. Figure 2 below shows some results that I personally found very impressive – enough to get me to do some more research in this area.

Figure 2: Effect of Active Learning



This figure shows the impact of active learning techniques on three critical concepts from a first year physics course. The blue bars show students' initial understanding of 3 fundamental concepts; force, acceleration and velocity. The red bars show students' understanding of these same concepts after a semester of traditional instruction. Unlike some studies I could cite, the students actually know more after a semester of instruction – that isn't always the case! But even here what you can see is that the learning gains are quite modest. This result is distressingly common. It turns out that traditional instruction isn't very good at developing students' deep conceptual knowledge. Traditional instruction is particularly ineffective for repairing any misconceptions that students bring with them to the classroom. Fortunately, there are alternatives to traditional instruction. What you can see in Figure 2 is that some of this instruction is remarkably effective. The yellow bars show student understanding of these same concepts after a semester taught using active learning techniques. The improvements are both obvious and impressive.

I've spent the bulk of the presentation so far defining active learning and trying to give you some incentive to use it. What I haven't done is discuss practical things that you can do in your engineering classes to incorporate active learning. Let me correct that omission now by suggesting a couple of easy things that you can do:

- A minute paper:

  This typically takes one of two forms. Here's the first way this can work. Towards the end of the lecture, you would ask students to take out a piece of paper and write down the "muddiest point" from that day's class. You simply collect those scraps of paper from students as they leave. Then you skim the first 20 or so (no matter how many students are in class) and note the item that comes up the most often. The next time the class meets, you say something like, "It seems that many of you were confused about X (whatever it was). Let me take a minute to clarify that point." Then you move on. The one minute paper counts as active learning because the students are engaging with the material by trying to remember what you covered in class that day. This activity also provides useful information to you as the instructor, which you can use to improve your teaching. It's a win-win.

  The other way to use a one-minute paper is to ask, "What was the main idea from today's lecture?" Again, you give students a minute to answer this question at the end of class and then collect their responses on the way out. One of two things will happen when you skim the first 20 or so. You might find that most people correctly identified the main point, in which case you don't need to do anything. However, you might find that no one in class has a clue what the main point of the lecture was. When that happens you walk into class the next time and say something like, "It seems that many of you didn't identify what I thought the main point was from the last class. Let me take a moment to clarify that what I was trying to get across was X (again, whatever it was)." As with the first implementation of the minute paper, the activity both engages the student and provides useful information to you as the instructor. Everyone wins.

- Asking "non-rhetorical" questions

Most instructors ask questions, but most of those are rhetorical. For example, instructors often ask if anyone in class has any questions, endure two seconds of awkward silence and then move on. This is natural enough – two seconds seems like an eternity when you're waiting at the front of the room for someone to raise their hands, but of course it's not generally enough to encourage an 18 year old to raise their hands and admit what they don't know in front of their instructor and the rest of the class. The other way faculty ask questions is generally much more specific. For example, if I'm teaching thermodynamics I might ask, "If I have an equimolar mixture of ethylbenzene and toluene and double the pressure, what happens to the fugacity of toluene?" Then the instructor calls on someone, let's say Tom, in front of the whole class. In that situation, what's Tom thinking? If he's like most students, he's thinking "Why me?" What's everyone else in the class thinking? Again, most likely they're all thinking, "Thank God the professor didn't call on me!" Is anyone thinking about thermodynamics? No, it's a complete bust. All the instructor has done is to embarrass Tom.

What else could you do? Take the very same question and say, "In two minutes, I'm going to call on someone for an answer. Turn to a neighbor and see what you can come up with." After 2 minutes, call on a student at random. Again, one of two things will happen. Either the student will have figured it out in two minutes with the help of a classmate, in which case that student feels great. Alternatively, he or she may not figure out the answer and will have to admit that neither they or their partner know the answer, although after 2 minutes of discussion they may have some initial thoughts that they'd like to share. But they're not embarrassed because they know that they're not the only one who doesn't know.

Whether the student knows the answer or not is irrelevant because, for those two minutes at least, everyone in class is thinking about thermodynamics because they don't know who the instructor is going to call on. This simple variation of asking the same question succeeds much better than calling on students cold.

There are other things you can do to incorporate active learning (many of which are discussed on Richard Felder's homepage, which you can find by simply Googling Rich's name). But these two examples are enough to get the point across.

While these examples of active learning are easy to do, there are three common mistakes that faculty often make that reduce the effectiveness of active learning. I'd like to address each one so that you don't make any of these mistakes yourself.

Mistake #1: Always calling on volunteers

This seems like a friendly thing to do, but it kills the effectiveness of active learning. Why? Because once students understand that the instructor will never call on them, they will have less incentive to engage. When you ask them to turn to a neighbor to discuss your thermodynamics question, they'll talk about basketball or anything else – knowing that the token smart kid in the front of the room who answers every question as soon as it's asked will answer this question too when you call for volunteers. You need to give students some real motivation to engage to increase the odds of them doing it.

Mistake #2: Making the activity too long

Many instructors think that if they ask students to solve a problem they need to give everyone in class time to solve the entire problem before moving on. Since some students are faster than others, some students might complete the problem in 2 minutes while others take 20. This is a real problem for two reasons. For the students who get up at 8 o'clock in the morning to come to your class and finish in 2 minutes, they are stuck twiddling their thumbs for 18 minutes of class. They might as well have stayed home and they're justifiably annoyed with the instructor for wasting their time. The other problem is that if you give everyone in class 20 minutes to complete the activity, you'll never get through your syllabus. I know I've said that coverage isn't everything, but I don't have that much time to waste every class – especially given how unproductive that time is for the majority of students who have completed the problem in less time.

The solution to this problem is to realize that the point of the activity is simply to get people to engage. They don't have to finish the problem. Two minutes is enough time for students to dig into the problem and see whether they have a clue about how to solve it or not. It's also enough time for them to discover where they get stuck and what questions they have. That's all you need. After two minutes you can call on students and see where they are and provide the help they need "just in time".

Mistake #3: Making the activity trivial

Of course it's silly to ask students in your thermodynamics class to identify their favorite super power and why that's their favorite. While some faculty think active learning involves ice breakers like this, that's not the most common way faculty ask trivial questions. What's more common is to put students in groups of 3 and give them 5 minutes to answer a question that any one of them could answer on their own in 10 seconds. Rather than doing this, make sure that when you put students together for any length of time and ask a question, that the question is worth discussing for that length of time. All of us want our students to learn the material at a high level – so ask an intriguing, relevant question at that level.

If you avoid these three common mistakes, I'm confident that you can make active learning work for you. As I've said, there is tons of research out there that shows that this stuff works. In fact there's so much research support out there that I don't think anyone would ever fund additional research to answer a basic question like, "Is active learning more effective than traditional lecturing?" That question has been asked and answered so often and so consistently that it's not worth asking it again. That being said, when you look at what goes on in most of our classrooms, you find that most faculty aren't using active learning, which begs the question, "Why not?"

Some of my current research looks at this question. It's a pressing issue because NSF has invested a lot of money in funding research to show what works to promote learning. If faculty don't use the results of that research to inform their teaching, that money has been wasted and we won't see the benefits in terms of either student retention or student learning that we could and should be seeing.

When you survey faculty to see why they still rely predominantly on traditional lectures, the most common concerns that come up have to do with time. These concerns come in two flavors. First, faculty are busy and are concerned about how much preparation time is required to develop activities for active learning. Secondly, faculty are concerned about covering the syllabus and want to know if they can still cover everything they want to cover if they make time for "turn to your neighbor" activities in class. Since these questions are so common, let me address both of them here.

Question 1: How much time does it take to prepare activities?

Answer: Often, very little! Let's look at the examples I've mentioned so far in this presentation. In the first example, the instructor simply stopped lecturing and asked students to look at their notes and to ask a neighbor if they had a question. How much time does that take to prepare? Close to none! Let's look at another example – the "non-rhetorical question".   In this technique, the instructor asks the same question they were going to ask anyway. The only difference is that instead of calling on a student cold, the instructor will have students turn to a neighbor and discuss the question for a minute or two. How much additional time does that take? Again, almost none. Finally, the one minute paper speaks for itself. Even if it really takes 2 minutes to do, it's not much! The take is that while active learning can take significant preparation time (and some techniques like problem-based learning really do) it doesn't have to. Instructors can develop activities in very little time at all.

Question 2: If I do all these cute activities, can I still cover the syllabus?

Answer: Yes! I've suggested adding two or three short activities, most lasting a minute of two, to each hour of lecture. In that scenario, you're still lecturing more than 90% of the time. The syllabus is still safe!

There are other concerns that faculty frequently have, such as concerns about losing control of the class or about the 2 students in the back who will refuse to participate. Like the concerns about preparation time and course coverage, it turns out that these concerns are also easy to address. In fact, the concerns are so easy to address that it really begs the question, "With so much research support behind active learning, and with the common concerns of faculty so easy to address, why don't more faculty use it?"

For me, that's a very interesting question and one that is worth researching. As I've mentioned, I'm spending some time on that question right now, but I don't have a lot of hard answers for you. At the same time, I'd like to share my initial thoughts, drawn both from my research to date and from my extensive time working with faculty in workshops. I think one of the problems that we're facing in terms of faculty development is that faculty developers are guilty of the same mistake as instructors. That is, faculty development people like myself like to complain that instructors don't adopt the research that is out there. But many faculty development personnel don't use a research-supported model to get people to change. Instead we think, "If I show engineering faculty data that supports active learning, they'll believe the data and change what they do". That's a naïve thought and not at all supported by the research. We need to get smarter about developing and employing more effective models for promoting change.

Another thing that I've learned is that change is much more of an emotional process than an intellectual one. If change were purely intellectual, then showing people overwhelming data would work. But change is about letting something go before you're certain about what it is you're grasping after. Change is about giving up what is comfortable when you're not sure that you can pull off the new thing and make it work for you. Engineering faculty are often more comfortable with data than with talking about their feelings and as a result "feelings" isn't what comes up when faculty are resistant to adopting active learning. Instead, the resistance always *seems* to be about substance. In my experience, however, it's not really about data. Let me illustrate that with a couple of common conversations that I've had with colleagues over the years. To protect the innocent, let's call this hypothetical colleague Bob. (Because it's me telling the story, I'll appear to be the most reasonable person talking).

Bob: "Mike, if you want me to change what I do, you need to show me convincing data."

Me: "That sounds fair. I have lots to show you!"

Bob: "Mike, I can't trust *your* data. You have a known point of view and might be cherry picking only the supporting data. I need to find my own data."

Me: "That sounds fair too. Let me know what you find and we can talk about it."

Bob: "Mike, I'm way too busy to go find my own data! I've got a million other things to do!"

In cases like this, people like Bob want to convey that they're open to being convinced by data. After all, as engineers they believe in data. At the same time, you can see that Bob has used the illusion of being data driven to provide a perfect defense to ever changing. He requires data (reasonable enough). He wants to get his own data (reasonable enough). And he really is busy. But collectively these positions make it impossible for him to change and leave him incapable of ever getting to the point where he would have to change. He can comfortably go along doing what he's always done without feeling guilty about ignoring decades of research findings. After all, he's open to being convinced – it just hasn't happened yet.

The other common avoidance mechanism that comes up in conversations with faculty is to require infinite, perfect data to compel change. At the same time, these faculty require no data at all to maintain the status quo of traditional instruction. Conversations with instructors who adopt this position often go something like this:

> Bob: "If you want me to change, you need to show me data." (Sound familiar?)
>
> Me: "That sounds fair, here's a study that shows that active learning is more effective than lecturing."
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> Bob: "Did you see how they chose their control group? They used a quasi-experimental design rather than randomly assigned control groups. You can't tell *anything* from studies like that."
>
> Me: "OK, here's a study with the methodology you like. What do you think?"
>
> Bob: "But that's only 1 study. You can't tell *anything* from *one* study."
>
> Me: "O.K., here are several more studies."
>
> Bob: "But none of those studies involve classes like mine. My class (institution, department, etc.) is unique so none of those results are relevant for me!"
>
> Me: "But Bob, shouldn't we weigh evidence on both sides of the question? What evidence do you have that how you're teaching now is better than the methods supported by these studies?"
>
> Bob: "They've been lecturing for 500 years. They wouldn't keep doing it if it wasn't the best thing to do."

And so it goes. If I had a dime for every rigorous defense of traditional lecturing like this that I've heard over the past several years, I'd be retired somewhere on a warm beach. (Actually that's not true, I love teaching). The point of sharing these (real) conversations is to emphasize that bringing about change requires much more than having overwhelming data. Exactly what it does take is an open question, but it's a question worth examining. Fortunately, there are a lot of people now looking at that question and I'm hopeful that as we get smarter about how to bring about change, the potential for active learning to improve engineering education will be realized. In the meantime, I want you to leave with an understanding that active learning is both effective and that it can be surprisingly easy to do.

On that note, I'm happy wrap up the formal presentation and to take your questions and comments. In particular, I'd like to hear your ideas on why active learning isn't adopted more broadly and what it will take to bring that about.

Thank you.

References:

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2. Felder, R.M. (2009). "Active Learning: An Introduction." ASQ Higher Education Brief, 2(4), August. See also <http://www.ncsu.edu/felder-public/Student-Centered.html>.