# USING ACTIVE LEARNING TO IMPROVE TECHNICAL TEXT COMPREHENSION AND INCREASE STUDENT PARTICIPATION

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## Abstract

**A technique for getting students to read a technical text in preparation for in-class discussion is presented. In this technique, the instructor writes critical thinking questions for the text. The students are given a reading assignment and the questions, and are asked to be prepared to discuss the questions in the next class. Students are held accountable for the reading by the instructor's evaluation of their in-class performance. This technique has been successfully employed in several upper-level engineering courses, and has resulted in better learning.**

### I. Introduction

It is generally accepted that active learning is better than passive learning. This is supported not only by research (Lambert and McCombs, 1997), but by common sense. In spite of this, lecture remains a heavily used teaching technique in engineering courses. For example, a survey of engineering faculty conducted in 1999 (Brawner et. al., 2002) showed that while 60% of engineering faculty used active learning techniques at some point during the semester, only 22% used them weekly or more often. There are several reasons for this, including a need to cover material (which can be done efficiently in lecture); a limited knowledge amongst faculty about active learning methods; and concerns over the amount of time it takes to develop learning activities.

An approach commonly used by engineering faculty for lecture courses is to read a section of the course text, process the information, re-write the information in a way that makes sense to the instructor, add additional information or examples where appropriate, then write and deliver a lecture. The students then dutifully copy the lecture notes from the board to their notebooks, usually without thinking about what they are writing. In this situation, the teacher is doing most of the learning, as evidenced in the well-known maxim (amongst teachers) that the best way to learn something is to teach it.

One could argue that the roles should be reversed – the students should prepare and give the lecture, and the teacher should evaluate the student's presentation. This is impractical, since the amount of time it would take even good students would be excessive, given their limited knowledge of the subject. This does not mean, however, that asking students to read and process information prior to a class cannot be done, and is in fact standard practice in some non-technical courses, such as literature courses. By

contrast, it is almost assumed that many students will not read the text in many technical courses, but merely use it as a source of examples, problems, and technical data. At the end of the course students sometimes complain that the text was not necessary, and with good reason – the faculty have already summarized the important information and handed it to the students!

The reasons for not using texts as a basis for classroom discussion in engineering courses include a sense that the material is too complicated for the students to pick up on their own, so the role of the instructor is to interpret the text and present it in a clearer manner. This may have been a valid stance at one time, but the quality of undergraduate engineering texts has improved dramatically over the past few decades. Most of the technical texts available today are accessible to the average undergraduate student. Some of them have been evolving over a period of 20 or 30 years, as the authors have learned how to better explain the material. This should lead an instructor who has never taught a particular course before to question whether it makes sense to summarize a well-written presentation that has been developed over 30 years by someone who is an expert at teaching that course.

The thoughts outlined above have led this author to experiment with assigning students a section of text prior to class, then discussing the text in class. This approach has been employed in three different courses – a second semester senior-level technical elective, a required first semester senior-level course, and a required first semester junior-level course. Section sizes ranged from eight students to 40 students. The technique has been used in varying amounts, from a handful of classes to an entire semester. In this paper, implementation details of the technique are discussed, as well as some conclusions as to its effectiveness.

The primary motivation for experimenting with this technique was to improve student learning. Improved learning should occur for three reasons – first, the students should be able to learn the easy material on their own, so class time could be used to discuss more difficult concepts and apply the concepts to different situations. Second, the technique would require students to think about the concepts before class and discuss them during class – that is, to actively engage with the material. Third, the focus of instruction would shift from having students learn material to teaching students how to read and interpret the text, which is a more useful lifetime skill. In addition to improved learning, it was presumed that a livelier classroom would be more fun, and that student evaluations of the instructor would improve.

## II. Active learning and text comprehension

There is no consensus definition of the term "active learning," but there are several elements that are commonly used when describing it. Chickering and Gamson (1987) state that for students to learn they must do more than listen – they must be engaged in higher-order thinking tasks such as analysis, synthesis, and evaluation. Some authors are more specific – for example, Bransford et. al. (1999) suggest that true active learning requires students to take control of their own learning; the U.S. Department of Education (1995) presumes that active learning is project-based. However it is defined, it is broadly accepted that active learning requires students to take some action that results in their thinking about the material in a meaningful way.

Active learning is not a new concept – it goes back at least as far as Socrates – however, prior to 1970 there was no systematic study of teaching in a scientific manner (Marzano et. al., 2001). Since that time a number of studies have been conducted to measure the effectiveness of active learning. Marzano et. al. summarize the results of studies on a variety of specific active learning instructional strategies such as asking students to identify similarities and differences, summarizing and note taking, homework, and cooperative learning in a K-12 environment. They show average percentile gains in learning for the experimental groups over the control groups due to these activities range from 22 to 45 points. Similar results are presented by Prince (2004) regarding active learning strategies such as introducing student activity into traditional lectures, promoting student engagement, collaborative learning, cooperative learning, and problem-based learning.

Teaching strategies are not purely "passive" or "active," but instead are on a continuum between the two. For example, lecture, which is normally thought of as a passive strategy, can be made quite active. Ruhl et. al. (1987) showed that students will learn significantly more if the faculty member pauses three times for two minutes during each lecture to allow the students to consolidate their notes. In the author's own experience, even a 50-minute traditional lecture can be made "active" if the student thinks about why the instructor took a given approach, or tries to anticipate what the instructor will do next. In the sciences and engineering, homework problems, which are generally considered active strategies, can be made quite passive if the student simply plugs numbers into equations without thinking, or works in a group in which one of the students does the real work and the others just copy. The true test of whether a strategy is an active strategy is whether it requires the student to critically think about the issues. Strategies such as group discussions, problem solving, case studies and journal writing are more likely to result in active thinking than strategies such as listening to a lecture or reading a book, but by themselves they do not necessarily result in active learning. The student must be engaged.

There is also a wealth of research regarding best practices in text comprehension. Marzano et. al. discuss strategies for summarizing, and conclude that to effectively summarize, students must delete, substitute, and keep information, which requires that they analyze the information at a fairly deep level. Tierney et. al. (1995) present a number of reading strategies, geared primarily for either general literacy or K-12 students. Some of these strategies, however, are broadly applicable, such as discussion groups, encouraging students to develop their own questions and adopt an active and inquiring attitude to reading, and vocabulary development. Simpson and Nist (2002) discuss strategies specifically for students at the college level. One of their suggestions is to provide activities that force the students to examine their personal theories about reading. By this they mean that students arrive at college with pre-conceived notions about how to read effectively. For example, students who took high-school biology classes may have found that they were successful by simply isolating and memorizing key terms – a surface-level strategy that will not be effective in upper-level college courses. They also suggest that instructors use direct instruction over time rather than simply assessing and evaluating – that is, model the reading process for the students, provide examples, then have the students practice and evaluate the use of the strategy in their own reading.

Whatever strategy is used, it is clear that one cannot simply assume that students know how to read effectively; they must be taught. There also must be specific actions that the students take that force critical thinking, rather than simply reading the material at a superficial level. It is in the processing of the information that learning takes place, not in the receipt of that information. By asking students to summarize, provide definitions, compare and contrast, and discuss important issues, they will necessarily have to think about what they have read, which should result in better comprehension and learning.

## III. Description of the technique

The technique described in this paper is both simple to implement and consistent with the research described above. The procedure for the instructor is summarized in Table 1, with additional details in the text that follows:

**Table 1 – Summary of Instructional Procedure**

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| 1. Read the text, making notes and highlighting important issues. |
| 2. Identify 5-10 key issues or questions. |
| 3. Write questions for the students. |
| 4. Give questions to the students at least one class in advance. |
| 5. Call on individual students to answer specific questions, making sure the response is a paraphrase, not an exact quote. |

Instructor preparation for a class consists of selecting a section of the text (usually 10-15 pages), reading the text, making notes and highlighting important issues, and writing questions for the students to answer. It is important to keep the reading assignment short enough so that students do not feel overburdened by the reading. When reading the text, the instructor identifies the five to ten most important issues raised by the reading, as well as any questions that come to mind. These issues and questions are then written in the form of questions for the students. This process usually takes less than an hour to prepare for a 50 minute class period – well below the time typically required to prepare a traditional lecture.

As an example of the questions, consider the following section of text from "Fundamentals of Aerodynamics" (Anderson, 2001), where the author is discussing a method for modeling the flow of a fluid around a cylinder:

> "Note that the $\psi = 0$ streamline, since it goes through the stagnation points, is the dividing streamline. That is, all the flow inside $\psi = 0$ (inside the circle) comes from the doublet, and all the flow outside $\psi = 0$ (outside the circle) comes from the uniform flow. Therefore, we can replace the flow inside the circle by a solid body, and the external flow will not know the difference."

The students are asked to discuss the following question: why does the streamline $\psi = 0$ represent the surface of the body? This question is fundamental to understanding the modeling approach used in aerodynamics, and the answer is completely contained

within the quoted section of text, but it is only clear to someone who understands the terminology that is used. The students could quote this section of the text, and it would be a correct answer to the question, but it does not indicate an understanding of the concept. In cases where a student quotes a section of text, the instructor will usually ask someone else in the class, "using your own words, what did he (or she) just say?" Students quickly understand that they need to talk about their understanding of the text, rather than simply quoting it.

As a second example of a question, the instructor might ask if a particular equation in the text is correct. Usually it is, although there are times when there are errors in the text. The point of the question is to make sure the student understands where the equation came from, and can generally follow the math, physics and assumptions used in its derivation.

There are several reasons that it is necessary to develop questions for the students. It highlights the critical issues, which can be difficult for students to do on their own; it forces the students to think about the issues that are raised; it provides a basis for classroom discussion; and it allows the instructor to assess the students' level of understanding of the text. In the context of the research discussed earlier, the instructor is modeling reading for the students, forcing them to actively engage with the material, and assessing how well they have engaged.

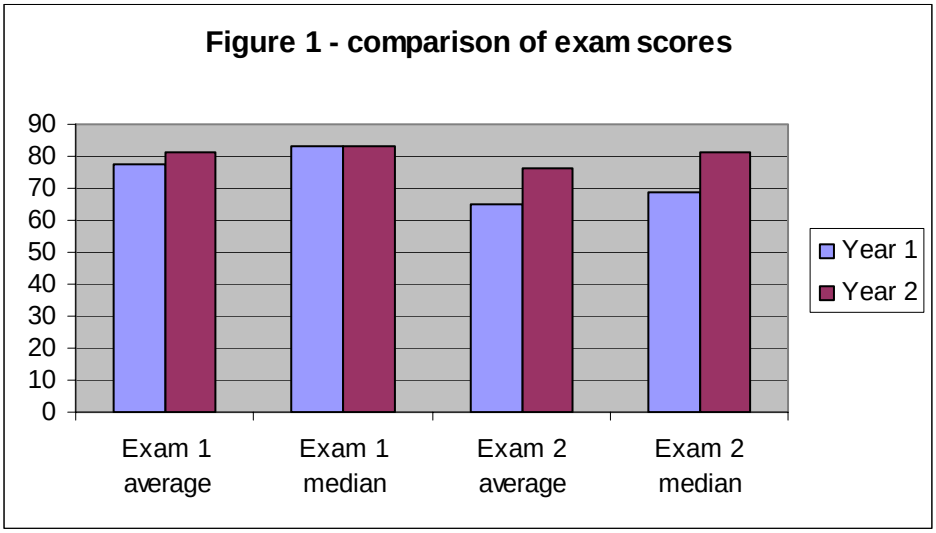
Once the questions have been written, they are given to the students at least one class period prior to the class in which they will be discussed. The students are instructed what to read, and are sometimes told that certain sections can be skimmed. They are told to be prepared to discuss the question in class, and do not have to hand in answers. They are also asked to develop a question of their own for each section. Students have indicated that it usually takes between 30 and 60 minutes to read the text and prepare answers to the questions, depending on the material covered, and have also indicated that this is reasonable.

During the class period in which questions are discussed, the instructor will ask specific students to answer specific questions. It is important to do this to make sure the students do the reading. In the class of eight students this was easy, because every student could be asked at least one question during each class period. In larger classes some method of keeping track of who answers questions must be employed. The author has used check sheets, and while they ensure participation from all students, the process of tracking students on a form tends to distract from the discussion. The technique that has been used most recently has been to mentally keep track of student participation, making sure to identify the student by name, which seems to work well. Correct answers are not necessary – the point is to get the students to read and think about the text. In fact, incorrect answers can be more educational, since a discussion about why the answer is incorrect can ensue.

## IV. Results

In the course in which this technique was first used, the first two exams were identical to those given the previous year, when traditional lecture was used. The technique was not employed until after the mid-semester break, so the material on the first exam had been taught using traditional lecture, and most of the material on the

second exam had been taught using this technique. The scores on the first exam were very close over the two semesters – the average differed by less than 4%, and the median was identical. On the second exam, the average was 11 points higher and the median 12 points higher for the course taught using the present technique (see Figure 1), and the entire grade distribution shifted up. While the sample size was small (eight students in each course), the improvement was significant enough to be a strong indicator that learning had improved.




One of the concerns that faculty have about active learning techniques is that they take too much time to develop, and take up too much class time. The author found that the present technique was actually less work than preparing traditional lecture (assuming lecture notes are being prepared for the first time), and material was covered at the same pace (and sometimes faster) than using traditional lecture.

Since the students are more involved in discussion, the instructor is better able to evaluate student knowledge than by using more traditional techniques alone. There were several instances where particular students performed very well in class, and it was clear that they understood the material, yet their exam scores did not reflect a comparable level of knowledge. The students would typically claim that they did not sleep well the night before the exam, or weren't feeling well, or got stuck on a particular problem, or maybe even say they couldn't understand why they didn't do better. The author's usual response to claims like these was to say "let's see how the next exam goes." Using the technique presented here, the author could say "yes, I know that you know more than is reflected on the exam," and was in a better position to determine a final course grade using alternate avenues for student assessment.

The author has found the present technique to be a more enjoyable way of teaching than traditional lecture. There is more participation from the students, and the atmosphere of the class is much lighter. The author believes that this has been partially responsible for a significant increase in student ratings of teaching effectiveness.

Student comments about this technique were mostly positive. The first time this technique was attempted, one student said, "Don't ever go back to the old way." In

another course, a student said that "open discussion on reading helps to create multiple views on topic leading to a better understanding of material." In a third course, a student thought the "idea of giving us advance questions to answer during class discussion was very helpful in understanding the material."

There are some disadvantages to a discussion-based format for teaching engineering courses. First, it assumes that the instructor really knows the content. If, for example, an instructor is teaching a new course outside his or her immediate area of expertise, a discussion-based approach can be dangerous, since the instructor has less control over how the class proceeds. In these cases it is much easier (and probably more effective) to structure the class using a traditional lecture format.

Second, this approach assumes that a truly good text exists for the course. The text must be written in a style that is interesting and accessible to the typical undergraduate student, and must be relatively free from errors. If the instructor really feels that he or she can explain the material better than the text does, then it is better to go ahead and do so.

Third, some students do not like the technique. Some students have learned how to be very successful in a traditional lecture course, and can in fact learn quite well in that mode. A discussion format can be frustrating to these students, who want to get to the material as quickly as possible.

Fourth, some students have difficulty with the lack of structure. One advantage to a traditional lecture format is that by coming to class, students end up with a clear summary of what is important in the course, and have the "correct" answers in their notes. In a discussion-based class, students can give incorrect answers to questions, and other students might not fully realize that the answers are incorrect. The author has taken two actions to mitigate this issue – posting lecture notes (which had been developed for earlier semesters) on the course Web site, and making it clear to the class if a student makes an incorrect statement. Both of these actions were suggested by students during an in-class assessment of the technique.

Fifth, the technique requires the students to actually do the reading and be prepared for class. As previously mentioned this has generally not been a problem, but one student confided in me that she just didn't feel like doing the reading one day, so she skipped class rather than face embarrassment. Her suggestion was to give out a few "pass" cards at the beginning of the semester. Students could use these for any reason during the semester without question from the instructor. The author believes that this is a good idea, and plans to experiment with it in the future.

It has become clear to the author that this technique can be very effective, but must not be overdone. Different students have different learning styles, and it is probably too much to expect a student to be prepared for every single class period, since they do not control schedules for exams, assignments, and projects for other courses. Based on several semesters of experimentation, the author believes that an optimum use of this technique is about once every two weeks.

## V. Summary

This technique is an easy method for encouraging students to read their text, and is useful as a mechanism for leading a discussion in class. It has been successfully

employed in junior- and senior-level engineering courses, and has been effective in improving learning, making the classroom more fun, and improving student evaluation of teaching. Its effectiveness as an instructional strategy is consistent with research on learning generally and text comprehension specifically. It is necessary to hold the students accountable for their assignments, but it must be done in a way that is not overbearing. If used sparingly, it can be part of an effective mix of active learning techniques.

The general approach discussed in this paper should also be effective in non-engineering courses. The nature of the material in other technical disciplines such as mathematics and physics is similar to that in engineering courses, so the technique could be used there without modification. Application of the technique to non-technical courses would probably require some modification of the approach, especially in the formulation of the questions.

## References


Anderson, John D., Fundamentals of Aerodynamics, 3rd edition, McGraw-Hill, 2001.

Bransford, John D., Brown, Ann L., and Cocking, Rodney R., Ed., How People Learn: Brain, Mind, Experience, and School, National Academy Press, Washington, D.C., 1999.

Branwer, Catherine E., Felder, Richard M., Allen, Rodney and Brent, Rebecca, "A Survey of Faculty Teaching Practices and Involvement in Faculty Development Activities," *Journal of Engineering Education*, Vol. 91, No. 4, October 2002, pp. 393-396.

Chickering, Arthur W., and Gamson, Zelda F., "Seven Principles for Good Practice," *AAHE Bulletin*, Vol. 39, March 1987, pp. 3-7.

Lambert, Nadine M. and McCombs, Barbara L., ed., How Students Learn: Reforming Schools Through Leaner-Centered Education, American Psychological Association, Washington, D.C., 1997.

Marzano, Robert J., Pickering, Debra J., and Pollock, Jane E., Classroom Instruction that Works: Research-Based Strategies for Increasing Student Achievement, Association for Supervision and Curriculum Development, Alexandria, VA, 2001.

Prince, Michael, "Does Active Learning Work? A Review of the Research," *Journal of Engineering Education*, Vol. 93, No. 3, July 2004, pp. 223-232.

Ruhl, Kathy L., Hughes, Charles A., and Schloss, Patrick J., "Using the Pause Procedure to Enhance Lecture Recall," *Teacher Education and Special Education*, Vol. 10, No. 1, 1987, pp. 14-18.

Simpson, Michele L., and Nist, Sherrie L., "Encouraging Active Reading at the College Level," in Comprehension Instruction: Research-Based Best Practices, C. Block and M. Pressley, ed., The Guildord Press, New York, NY, 2002, pp. 365-379.

Tierney, Robert J., Readence, John E., and Dishner, Ernest K., Reading Strategies and Practices: A Compendium, Simon and Schuster, Needham Heights, MA, 1995.

U.S. Department of Education, School Reform and Student Diversity, www.ed.gov/pubs/SER/Diversity/glossary.html, 1995.