Efforts to build student engagement in an engineering analysis course in mechanical engineering

Aaron Smith
Mechanical Engineering Department, Mississippi State University

Abstract

The complex nature of engineering problems requires engineering students to have a mature grasp on a broad range of math and science concepts. For this reason engineering students take a large number of high level math and science courses before entering engineering courses. Even with success in these math and science courses, students can still struggle with problems in the engineering curriculum which commonly require them to incorporate several high level math and science concepts into a single problem. Additionally, low student engagement in highly mathematical courses make it difficult to help students gain this maturity. This paper discusses the use of the pause method to encourage student engagement and to help students improve mathematical maturity in an engineering analysis course.

Keywords

Instructional methods, conceptual learning, student maturity

Introduction

The inquiry discussed in this article was conducted in a course entitled Engineering Analysis (EA) which is in the Mechanical Engineering curriculum at Mississippi State University. The EA course is an applied mathematics course that operates as a bridge between the engineering curriculum and general math and science courses. The EA course reviews several concepts covered in previous courses and applies them to engineering problems. Also, the course introduces numerical methods.

Each unit of the EA course begins with derivations and method development. These units typically connect several concepts from mathematics and science courses to engineering problems. While the students have worked with these concepts before, this course challenges the students to have a more mature view of the concepts. It is very uncommon for students to have a strong conceptual foundation of the Mathematics and Science curriculum when they enter engineering courses. For example, one section in the Engineering Analysis course covers differential equations. At the beginning of the course the instructor commonly asks the question: "What is a differential equation?" Even though every student is required to have had an entire course with the title "Differential Equations," almost 100% of the students are unable to describe differential equations at all. Students also commonly have a very weak conceptual understanding of other concepts such as functions, roots of an equation, Newton's 2nd law, kinetic and potential energy, and other foundational concepts.

Many have attributed this student concept acquisition deficiency to educational methods that encourage passivity in the classroom. Ron Ritchhart and David Perkins have written of how traditional education methods can lead to student "mindlessness" in the classroom where students receive information uncritically[1]. They propose a specific method of discussion and questioning in the classroom to encourage the disposition of mindfulness in students. Michael Prince has given a summary of the many educational research efforts to promote active learning[2].

In the EA course the instructor has observed that many of the students tend to receive the notes passively and uncritically until they are faced with an example problem or a homework assignment. As the concepts are refined in the notes, the students just take the notes without trying to improve their understanding. Then, the students become very engaged when an assignment is due or a test is coming up. However, at this point, there is often too much to learn in too short a period of time. This lack of student engagement during the lecture also leaves the student to develop understanding on their own without the benefit of the instructor.

For maturity in mathematical and scientific concepts the students need to be able to wrestle with the details of the derivation of each concept. They need to clearly understand not only how to use the methods, but also when it is appropriate to use them. They need to make connections with and build off of previously learned concepts. They need to understand the assumptions that have been made and the limitations of the method.

Several studies have discussed the benefits of pausing in the middle of the lecture to give the students a few minutes to discuss the notes among themselves[2, 3, 4]. Allowing this informal time has been shown to increase retention by encouraging the student to be more active in the learning process. This study applies a version of this pause method in an effort to improve student acquisition of mathematical maturity by getting the students to wrestle with the notes earlier. In this study, the students were periodically given time to reflect on the notes and discuss them with other students during lectures as described below.

In Class Reflection/Discussion Time

During several lectures of the Engineering Analysis course, students were given a two minute break after receiving a section of notes that dealt with theory or derivations. The students were asked to break into groups of 2-3 and discuss the following two questions:

1. What are you unsure of related to today's notes?

2. What are you wondering about related to today's notes?

The first question was designed to encourage students to question their understanding of the method derived and the assumptions and limitations involved. The second question was designed to encourage students to make connections with previous knowledge and consider the potential applications of the method.

After they were allowed this time of discussion in groups, the students were given time to ask questions or make comments to the instructor about the topic under study. This method was used in 5 different lectures. Each time, the students generated several questions, which they asked

voluntarily. The types of questions asked fell into several different categories. Examples of each category are listed below:

- *Example questions about embedded base concepts*: What is tanh? How does regression analysis relate to significant figures? Is Newton's 2nd law how you find the DE's that we were given in our DE class?
- *Example questions about applications*: What all types of functions can you use newton's method for? Could the least squares method be used for quadratic or cubic functions? Do we use this method when there is no an analytical solution?
- *Example questions about the method*: What is next after finding the root? What do the z subscripts mean in the method for reducing a higher order ODE to a set of 1st order ODE's?
- *Example questions about justification*: Is this method needed? Can we just solve for H instead of using Newton's method?
- *Example questions about the objective*: What is the goal of Newton's method? Is the goal of regression analysis to average out the errors?
- *Example questions about the limitations with the method*: How do you know if your solution is accurate when using numerical solution methods? What types of DE's can be solved using Euler's method?

The questions listed above are paraphrases of actual questions from the students. Each of these categories look at different aspects of the concepts. In many cases the answers had already been implicitly stated in the notes or were in future notes. However, having students ask the questions themselves made them more active in the learning process. This facilitated a rich classroom discussion as opposed to just a one-way lecture. In theory, this method draws students to wrestle with the section concepts over a longer period of time and with more input from the instructor. This also allows students to gain more from the examples and other derivations in the same class period.

Summary and Conclusions

The goal of this study was to improve the process of student maturity acquisition in math and science concepts needed for engineering courses. The method used in this study was to give students a two minute break to discuss concepts with their peers, followed by time to ask questions to the instructor. In each case that this method was employed the students asked several questions. In the course instructor's experience, the number and variety of questions was unusually large at that point in each section of the course. This indicates that the students were led to be more engaged with the notes earlier in each section, and, therefore, were given a longer time to develop maturity. Also, the students were given more time to develop maturity with the help of the instructor, rather than having to figure out gaps in their understanding while at home. Future work needs to be conducted to quantify further the level of impact that this method has. Also, it would be interesting to subdivide the necessary areas of maturity and study how well this method addresses each area.

References

1 Richhart, R., and Perkins, D. A., “Life in the Mindful Classroom: Nurturing the Disposition of Mindfulness,” *The Society for the Psychological Study of Social Issues*, 2000.

2 Prince, M., "Does Active Learning Work?" Journal of Engineering Education, 2004.

3 Smith, K. A., et al., "Pedagogies of engagement: Classroom Based Practices," Journal of Engineering Education, 2005.

4 Ruhl, K., C. Hughes, and P. Schloss, “Using the Pause Procedure to Enhance Lecture Recall,” Teacher Education and Special Education, Vol. 10, Winter 1987, pp. 14–18.

Aaron Smith

Aaron Smith is an Assistant Clinical Professor in the Mechanical Engineering Department at Mississippi State University. He obtained his Ph.D. in Mechanical Engineering from Mississippi State University in 2012. Prior to teaching, he spent 3 years working as a senior engineer in research and development in the aerospace industry. He has research interest is in the areas of enhancing conceptual understanding in engineering education and integrating design engineering skills into the engineering curriculum.