

## **Learning by Teaching: an Alternative Teaching Approach in Engineering Education**

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### **Abstract**

An alternative teaching approach was carried out in the Engineering Mechanics-Statics class, which is a second year undergraduate engineering course, at Penn State Fayette, The Eberly Campus. The new approach deviated from the universally followed format of continuous lecturing by the instructor and involving teaching assistants in recitation sessions. The undergraduate students themselves were sporadically but evenly asked to teach and learn from each other in this approach. Initial results are encouraging. This paper outlines this new way of teaching. It shows the ways in which it improves teaching. Limits and constraints associated with this way of teaching are also explained.

### **Introduction**

In recent years, there has been a great emphasis on developing and implementing new and innovative methods and techniques to enhance undergraduate engineering education. Engineering educators have been strongly encouraged to explore potential ways to improve existing and gain new teaching skills. Universities nationwide are generally supportive in this regard in various ways. Many universities in fact request continuous teaching improvements through their promotion and tenure process. Further, state and federal authorities have created various programs to introduce and implement new ways of instruction to enhance undergraduate education. Various national organizations aim towards this objective. For instance, the American Society of Engineering Education (ASEE) is fully dedicated to promote engineering and engineering technology education.<sup>1</sup> The ASEE convenes an annual conference and exposition exclusively for this purpose. The ASEE makes the creation and implementation of new effective teaching techniques and new teaching trends one of its conference topics. The separate annual conferences by the ASEE chapters compliment this effort as well.<sup>1</sup>

Consequently, many educators have succeeded in developing and implementing a variety of new teaching methods in their courses. This includes for instance the use of remotely operated laboratories,<sup>2</sup> applying studio-based learning,<sup>3</sup> incorporating problem based learning concepts,<sup>4</sup> and promoting undergraduate students to learn graduate materials.<sup>5</sup> Even electronic and other games have been utilized to improve teaching.<sup>6</sup> All of this clearly illustrates that exploring new teaching approaches on a continuous basis is critical to enhance the education process.

## **Improving the Teaching Process**

The engineering education process involves two components. These are the instructor and the students. These two sides are important because they provide complimentary roles to each other. In other words, the education process involves teaching and learning. In general, the teaching component pertains to the instructor while the learning component belongs to the students. The education process can be advanced by enhancing either its learning or its teaching aspects.

The focus of what has been developed and implemented to improve the education process has been exclusively on only one side of the education process. Numerous initiatives and projects have been devoted to improve the teaching abilities of the instructors. There is however some emphasis on the learning habits of the students. Understanding these habits enables instructors to modify their teaching aspects to increase students learning. Nonetheless, this is still one way of improving the teaching skills of the instructors. Little effort has been devoted to explore the teaching potential of the students themselves to enhance the engineering education.

### **The Teaching Potential of Undergraduate Students**

Outside classrooms and generally speaking, undergraduate students tend to work in groups. They work together to complete course assignments and projects. They prefer to seek help from each other before giving a visit to the instructor. They study for short tests and final examinations together. They feel free to dispute each other and often correct each other as well. They engage themselves in long but seemingly constructive discussions and debates. That is, they teach each other and learn from each other at the same time. In fact, students in some situations are more receptive to new concepts and ideas if they are introduced by their peers instead of their instructor. All of these observations prove that students have the capabilities and willing to learn from each other, and equally importantly, they have a great potential to teach each other as well.

The above teaching and learning interaction between undergraduate students is performed marginally on the side. It appears to be very useful and practical because the students are involved in it by choice, and it seems to be an acceptable and a normal mode of learning. Therefore, utilizing this potentially important dimension under an official umbrella and under the careful supervision of the instructor will seemingly enhance the education process.

### **The Alternative Approach at Penn State Fayette**

An alternative teaching approach was carried out in the second year undergraduate Engineering Mechanics- Statics Course EMCH 11 at Penn State Fayette, the Eberly Campus in the fall of 2004. Unlike the traditional teaching approach, the new teaching practice utilized the potential of the students themselves to teach and learn from each other. That is, it implemented the concept of teaching by learning and learning by teaching. In essence, the class topic was conveyed by the instructor to a student who in turn acted as a delivery vehicle to the classmates. This is illustrated in Figure 1. For comparison purposes, the traditional approach is depicted in Figure 2.

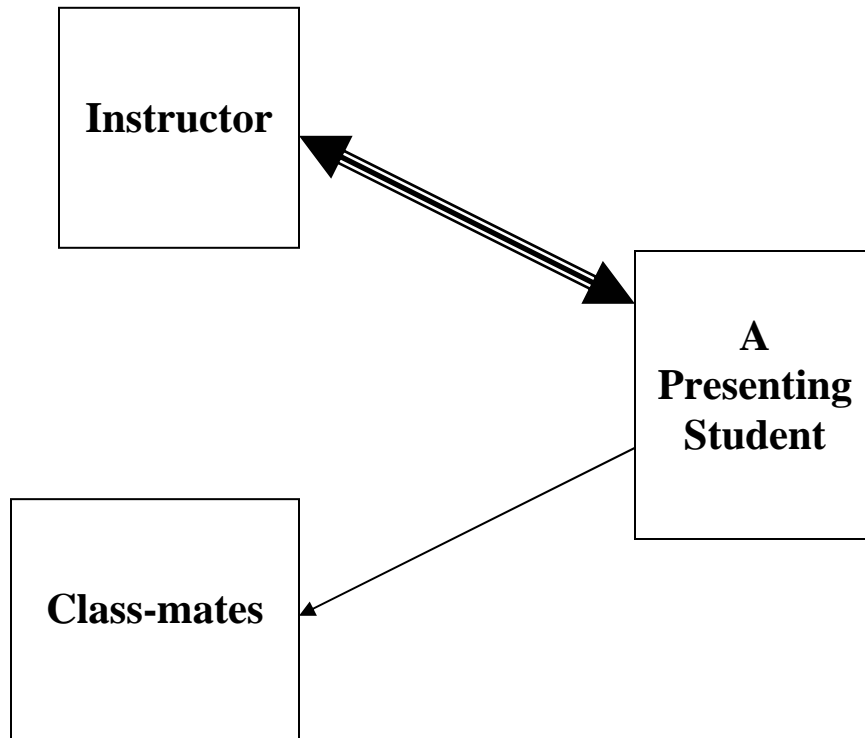


Figure 1. The Alternative EMCH 11 Teaching Approach at Penn State Fayette

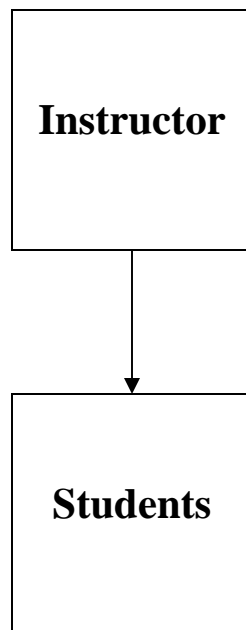


Figure 2. The Traditional Teaching Approach

Each student assumed the instructor's role for one class period. Each student chose the timing of this class period. The original plan called for an even spread through the fifteen-week long semester. However, all students' sessions were carried out in the second half of the semester. In normal class setting for this particular course at Penn State Fayette, the Eberly Campus, the instructor delivers all of the theoretical derivations in class. The instructor follows this theoretical background by solving problems. Teaching assistants (TA's) are not available at this particular campus to perform recitation sessions. These problems are chosen carefully by the instructor to illustrate the application of the theory at hand. In the new setting, the students did not opt to present theories in their teaching sessions. They however opted to apply the theoretical concepts to problems. The instructor met with each would be student instructor several times and for prolonged periods of time in preparation for the actual student's session. An integral part of this process was to give a lot of freedom to the student who will deliver the class. Students were totally free to choose the materials they would present to class. They also decided on the manner in which they presented their sessions. The instructor provided guidance and supervision in the preparation stages.

The students who gave the sessions were totally in charge of the class during these particular class periods. The instructor was merely a spectator. The instructor did not intervene in the class proceedings. The instructor was acting as an observer in case something incorrect and drastically takes place, but nothing of that nature happened. In fact, the instructor acted as and pretended to be a student attending the class. The instructor informed the students to expect this particular behavior. All of this was necessary to achieve the objectives of this new teaching technique.

Students' sessions were treated as an integral part of the course. Students were responsible for the materials covered in these sessions. This was fair because students were encouraged to ask questions and seek clarification during these special sessions. Additionally, and if needed, they were also invited to request help from the instructor after the completion of each of these sessions. Indeed, the final examination of the course contained parts of these students' sessions.

Traditionally, undergraduate students are not expected to participate in teaching. Consequently, the performance of the students in these teaching sessions did not have a bearing on their final grades. In our particular case, this seemed to have eased the tension associated with giving a presentation. In return, students performed better in their presentations.

As planned, each student assumed the capacity of the course instructor for one class. All of the sessions were well conducted. The students were fully prepared for their sessions. The student in charge engaged other classmates by asking questions and seeking participation from them. The class atmosphere was relaxed but serious in all of the sessions. Other classmates responded positively to this sporadic class setting. They acted as if the class was given by the instructor, and not by one of their own. They did not hesitate to ask questions. They in fact sought clarification frequently. The instructor was present in all except one of these sessions.

## **The Benefits of the Alternative Teaching Approach**

Everyone benefited from the application of this new approach. Students who were instructors even for one class period learned a lot from this new experience. Students listening to other classmates also increased their knowledge. Further, the instructor gained from this operation as well. In other words, the education process itself improved as a result of this new way of instruction. All of this is explained next.

The student who was going to be the instructor for one class period felt a sudden sense of urgency. This student realized that the spotlight would be on him or her to deliver a good presentation. As a result, the student spent extra time preparing for his or her session. The student met several times with the instructor in this process. All of these independent efforts made him or her understand the specific topic at hand very well. It is important to recall that this topic was within the scope of the course. Teaching this specific topic to the class made the student's own understanding of the topic at hand even deeper.

Other classmates learned the specific topic at hand from their classmate adequately. This is because the student who presented it was well prepared and the presentation was in close coordination with the instructor. The students found this way of instruction amusing and joyful. It brought a needed change to the class routine. Further, some students wanted to test their classmate on his or her knowledge of the presentation topic, and this made them pay more attention to the class. This resulted in an excellent interaction between the students and the presenter.

The instructor was an observer in these special sessions, and that was beneficial in various ways. This was extremely useful because it allowed him to see the ways by which his students think. This knowledge enabled him to improve his own teaching skills for this specific course and it will have a similar effect in the long term teaching career as well. Additionally, this experience helped the instructor to discover his own teaching shortcomings and mistakes. This was accomplished by listening to the student in charge and by observing the classmates who are listening and trying to understand. Teaching shortcomings and mistakes can be generally rectified but they have to be identified first. The instructor learned something else which is also very important from this process. By occupying a neutral seat, he learned possible and potential students pitfalls. In normal teaching setting, the instructor does not easily recognize these dangerous pitfalls while being busy giving a lecture. For future purposes, the instructor can incorporate this valuable knowledge to improve his teaching. The instructor in one way or another can effectively alert his students to avoid such pitfalls.

### **Students Comments**

Students liked conducting these teaching sessions. All of them agreed that they learned a lot because of their extra preparation time. Some of them found this to be challenging. Rising to this challenge was gratifying to them. There was a sense of ownership and pride among the students and that enhanced their learning process. All of them found this to be an interesting experience, and they did not mind repeating it again.

The classmates listening to a lecture by another student found this technique to be useful and amusing. All of them agreed that each student delivered a very good class presentation. No one complained about these sessions.

A formal quantitative assessment on this teaching approach was not conducted. However, the students are planning to give their assessment in two different forms. First, they are in the process of writing a manuscript on this learning experience, and they hope to present and publish it at a future ASEE conference. This article will be written from their perspective as students. Second, the coordinator of the Penn State Fayette Faculty Colloquium, which is a monthly event, has invited the students who took this particular class to give a presentation on this learning and teaching experience. The students are planning to give a full assessment on this alternative approach to the faculty members at Penn State Fayette in this presentation.

### **Instructor's Observations**

The instructor was expecting the student who was going to give a presentation to be nervous and shaky. This did not happen. Every student was confident and the presentation was carried out smoothly. This may be attributed to the following two factors. First, it was a small class, and everyone knew each other. Second, each student made extended preparation efforts before the presentation.

There was a concern that the students who were sitting in the class would not take this seriously. This indeed happened but only in the first fifteen minutes of the first presentation. After this very short interruption, the operation took a serious turn and things moved in a proper manner.

The instructor made it very clear that he would not intervene unless there was a compelling reason. The students as expected were totally independent in their presentation. Consequently, they seemingly did not pay attention to the presence of the instructor.

On one hand, many of the presenting students engaged the class actively by asking for participation. It was very interesting to see that the pattern of participation from the students was very similar to that of the normal setting. On the other hand, students who were listening to their classmates asked the presenters questions frequently. The pattern was however different from the normal class setting. The students asked more questions in the new setting. Some students who usually do not pose questions to the instructor in his lectures posed questions to their fellow presenting students. These questions were indeed legitimate and interesting questions. It seemed that the students felt more comfortable posing questions to their peer than to their instructor.

It was very intriguing to see that students tried hard to accentuate their own teaching styles. Nonetheless, it was very conspicuous and remarkable to see that they actually emulated the instructor's teaching style. They almost used the instructor's ways in explaining and presenting the material. Frequently, the instructor felt like he was listening to himself in these presentations. At first, it was awkward. However, this turned to be gratifying to him because it showed that students were listening to the instructor. Further, the instructor could see from first hand experience his own teaching faults. The reason behind this imitation was not clear at all.

On one hand, it might have been unintentional. That is, students imitated their instructor intuitively. On the other hand, it was possible that the students wanted to please the instructor by using his teaching techniques.

## **Limits and Constraints**

As usual, there are limits and constraints for each new approach besides its advantages. The new approach is not an exception to this general rule. Some of these limits and constraints are outlined next. To start with and unfortunately, the new approach can be applied effectively only to small size engineering classes. In a small class, the instructor can afford diverting a few classes to the students' presentations. A fledging undergraduate engineering student can manage to instruct a small class, but it will be an extremely difficult situation with a large class. Students in small classes may be convinced to take this approach seriously, but a large class will be very skeptic. Additionally, students may not be willing to participate in this approach and the instructor neither should nor can force any student to perform this task. Further, academically strong students tend to gladly accept participation in this approach, but weaker students have the tendency of rejecting it. Also, this approach may seem viable to the instructor, but it may not appeal to his or her administration. In addition to the above obstacles, not all undergraduate engineering courses may be suitable for this approach. Finally but most noticeably, this new approach requires extra efforts from the instructor. Instead of giving a one-hour lecture, the instructor needs to spend extended hours with the student who will give the same lecture. This has to be done with each student in the class.

## **Summary and Recommendations**

Involving undergraduate students in actual teaching in carefully chosen sporadic classes, which was implemented in an engineering course at Penn State Fayette, was found to be a viable alternative to the normal format in which all of the teaching is performed by the instructor and graduate teaching assistants. The undergraduate students themselves benefited from this new teaching experience, and that has its remarkable and positive impact on their learning practices. The instructor himself learned many things from this new approach, and that has its pronounced and constructive influence on his teaching abilities and skills. All of this enhanced the education process in this particular course. This approach seems to be useful in other engineering undergraduate courses as well. Instructors at other institutes are encouraged to try this new method of teaching, but they have to be careful with its limitations and constraints.

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