# Critical-Thinking Approach to Teaching Mechanical Engineering

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## 1. Introduction

Critical thinking, in the context of teaching, means a careful consideration of the material learned by students in class and outside of it. It is very natural to accept without questioning material presented by the teacher, textbook, journals, internet, etc. Several examples are presented that show how detrimental this approach is to student's learning. Questioning, or carefully considering, requires courage, also to admit incompetence, understanding of the basics, and often hard work. That's why many students avoid it. History is full of examples of scientists, researchers, and engineers who avoided critical thinking in their careers. Those who did apply critical thinking, contributed to the progress in their disciplines. It may seem that lack of critical thinking occurred only in the past. We often are so deeply engaged in solving problems that we overlook that there often is another possible approach to a problem. In the bibliography[1-9], several references are given to publications that deal with critical thinking as a way of living. In this paper, only limited experiences are presented that relate to a few courses in the Mechanical Engineering Technology Department at Purdue University.

## 2. Critical thinking as applied to course work

Students should understand the scientific principles in a given course. It will help them notice discrepancies between the theory and practice when they do occur. This will promote learning, but only when students pursue the explanation for the discrepancy. Was it due to their lack of understanding of the principles, was there an error in the experiment or application, or, was it simply due to typing error in the textbook? Students often expect excellence from textbooks, other course materials, laboratory equipment, and often are taken by surprise when the outcome is not what they had expected. This is especially evident in laboratory exercises. There are often a few students who blame their problems with laboratory assignments on the malfunctioning equipment, poor instruction, confusing instructions. In MET 382 Controls and Instrumentation for Automation students are asked to submit recommendations for improving every one of the six multiple-week laboratory assignments. They are asked to avoid complaints, and to concentrate how the assignments can be made better. While it is understandable that encountered problems are very helpful in identifying the improvements, many students have trouble moving beyond complaining about problems.

Whatever the reasons for such a behavior, it can be changed. Depending how resistant a student is to a change in his or her approach, it may take even a full semester to change the approach. One student comes to mind who, when given a problem to solve in a MET 230 Fluid Power laboratory assignment, would demand providing him with the answer, and refused to work. He would argue that it was the instructor's duty to tell him the answer. He expected the teacher to teach him, and did not appear to see that he himself could be his own teacher. The instructor gave up at first and gave the student the answer, mainly to avoid the disruption of other students' work. This student offered an excellent opportunity for the laboratory instructor to learn how to handle such an approach. This particular student shifted his focus from demanding ready answers to looking for them himself, when the instructor kept refusing to give in. This was a hard case, as it took almost the full semester for the student to change his approach.

Another, more common problem with laboratory exercises is when students select completing the assigned exercises without any additional involvement of their own. They would follow the instructions to the letter, even if they contained an error. They would have trouble understanding problems appearing during their work. They constantly ask for help. Some do not ask at all to avoid revealing their incompetence. As in the previous case, the instructor can have a great influence on the students. If the instructor does not give in, such students, even if there are several of them in a laboratory group, have to change their approach. Often the change is quite dramatic, and the student suddenly reveals great enthusiasm in learning the topic.

Part of the problem is that students often think a particular course is useless for them. They need to take it in order to graduate, and work only as much as to get the grade they need. It is often difficult to identify such students. If the instructor is sensitive to students' involvement, and tries to learn more about the reasons why they do not work as they could, it can reveal solutions. The instructor may remember a good student from a previous course who seems to be falling behind. A discussion with the student usually helps. Students appreciate when the instructor remembers their previous good course work, and often this is enough to change their attitude.

Class discussions are promoting critical thinking. Both students and teacher can learn from them. Students can ask for clarifications, which gives the teacher an excellent opportunity to present the material from a different perspective. Discussion may reveal discrepancies, omissions, errors, and other problems that otherwise would remain unnoticed, both by students, and the teacher.

Critical thinking can help a student to better understand a topic. A student would do an extra work to better understand a problem. Recently, an MET 382 student, who's homework assignment was to calculate time needed to empty part of a reservoir filled with liquid, built a model of the reservoir himself. He later told the instructor that this simple experiment helped him better understand a topic from a fluid mechanics course. And he was excited about his experiment. He could have ended up using Torricelli's theorem from textbook, with much less benefit.

MET Department recently decided to equip the Fluid Power Laboratory with several new test stands. The new stands allow students to build the circuits from scratch. The components can be easily attached to the board on the stand, and connected by hoses. The instructor had the opportunity to observe and compare students' involvement in a laboratory assignment. The same students, when working with old test stands, were much less enthusiastic about the assignment. The laboratory assignments need to be modified to accommodate the new stands, and often scaled back. This is due to the time needed for students to solve problems that would not show up on older stands. On the new stands, students take ownership of their circuits, understand them better, and are able to discover and solve problems. With pre-assembled circuits, it was difficult for the instructor to engage student into exploring problems, because they did not fully understand the circuit in the first place.

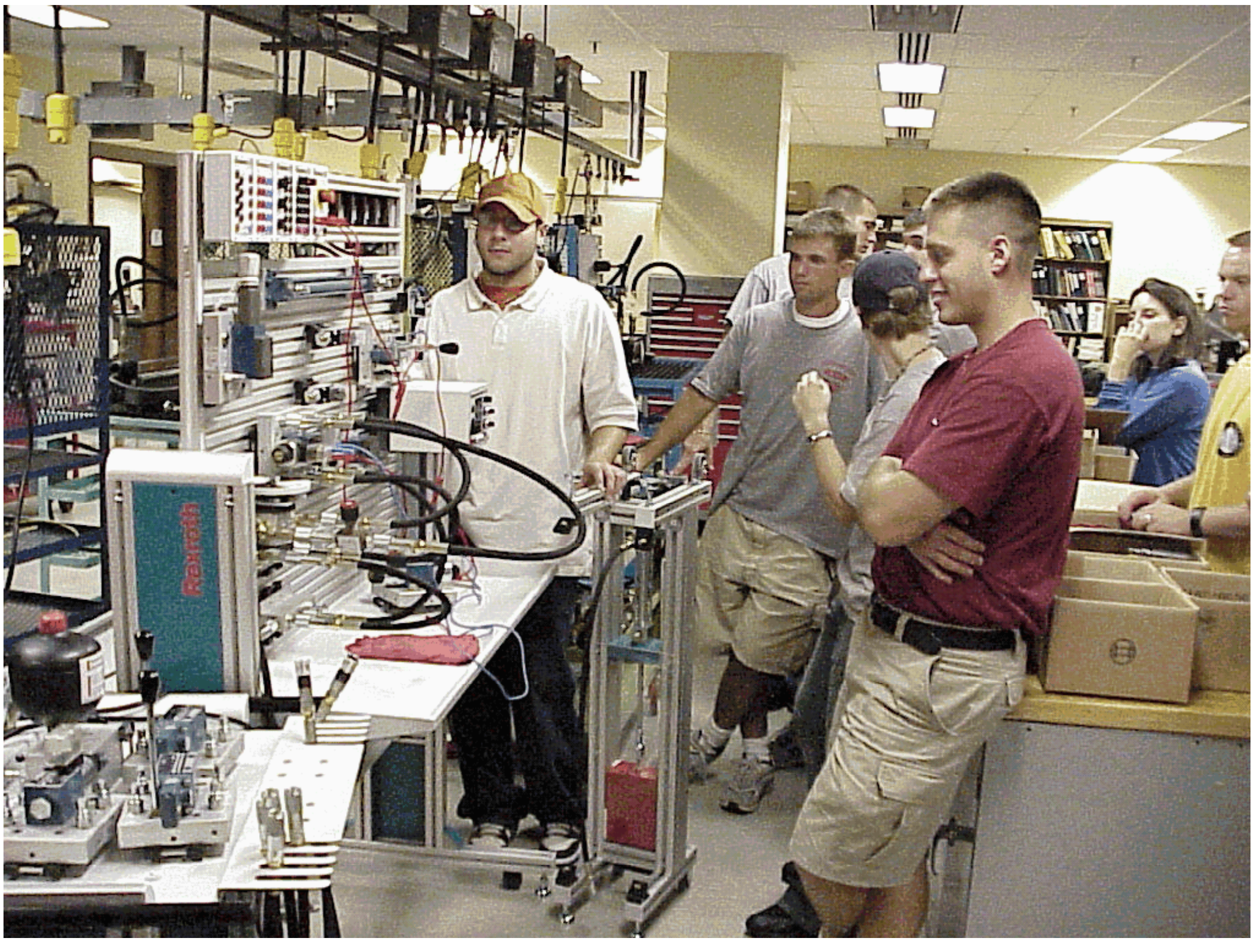


**Figure 1. Students in MET 334 Advanced Fluid Power look at their first circuit built on a new test stand**

Another way to promote students' involvement in the fluid power area is to use computer software to teach concepts that traditionally are difficult for students to grasp. It is difficult for a teacher to present a fluid power circuit in action by only using a chalkboard, or overhead. Computer software can do a better job much easier. First experiences with such software are very satisfying both for students and instructors. It's like switching overnight from a slide-rule to a calculator. As with any new technology, first excitement often gives way to some disappointments. When the limits of the technology, or software, are discovered, critical thinking has an opportunity to be applied.

## 6. Conclusions

Critical thinking is considered as an important component of a successful way of life. As such, it also applies to learning mechanical engineering. If applied fairly, in a humble way, and with integrity, it provides both students and the instructor with great opportunities to grow. It uncovers inappropriate attitudes, frees from impulsive thinking, and improves relationships. As a result, the effectiveness of the learning process improves. Students are better prepared for coping with problems they will encounter after graduation.

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