Session 1148

Teaching Critical Thinking

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Abstract

This paper describes the challenge of Teaching Critical Thinking to a class of physics students at TCI, The College for Technology in the fall semester of 2000. Besides achieving its goal of helping students to think critically, teaching critical thinking provides fun and students find it quite rewarding. Students are encouraged to work on creativity throughout the semester, in class, in laboratory experiments, on homework problems and in the creation of examinations.

1. Introduction

Students must be taught to think critically, communicate, and work together effectively. At TCI, The College for Technology we have over 4000 students who speak 100 different languages. In the EET (Electronics Engineering Technology) program, our students work toward an AAS degree in 5 semesters. Teaching critical thinking as part of the course curriculum is a goal.

Problem solving provides a key element in Engineering Training. To develop critical thinking, students are assigned teams. The members of each team have only English as a common language. Each team works on problems as a unit. Students learn to formulate word problems. They begin by drawing a picture of each problem and then discussing the objective of the problem.

Because the teams function as a unit, students discuss the problem and listen to the contributions of each member. Each team member explains the problem to the class in an oral presentation. In addition, all students write one composition each week on the current chapter. These assessments continue through the term.

11 Background of the class

TCI Catalog describes the subject of this paper as a physics class PHY-301 Physics 1. EET students take this course in the third semester. The fall 2000 class consisted of 14 students, 13 male and 1 female. The student ages ranged from 19 to 35. Four students were classified as evening students, which meant that they were coming to school during the day just for this course. Five students had been admitted to TCI with remedial status in English and Mathematics and two were admitted with GED's. Three students were white, two were Hispanic, five students were black, and two were Asian.

111 Course Goals and Content

The goals for students are to solve problems in physics, to think creatively and to develop interpersonal skills. Many students who have taken physics can talk about plasmas and Black Holes in Astronomy, but they cannot solve physics problems. TCI requires students to follow a syllabus, which includes basic mechanics, Newton's force laws, conservation of energy, conservation of momentum, universal gravitation, rotational motion, and waves.

1V Creative Requirements

Students learn creative thinking by following five major paths.

1. Compositions
2. Classroom lectures
3. Homework
4. Laboratory experiments
5. Class participation

V Examples of Creative Projects in the curriculum

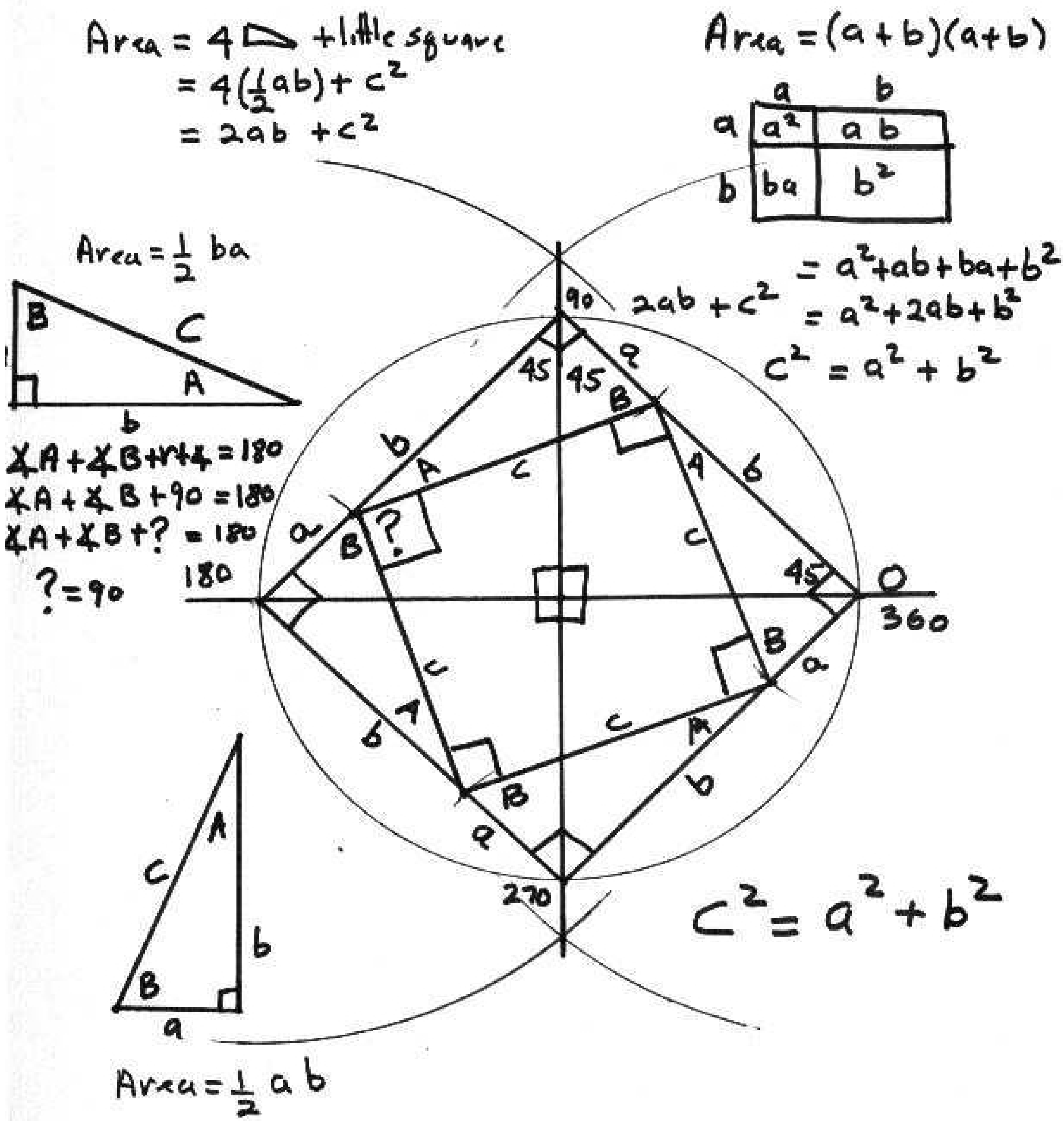
The textbook for the course is "Physics for Scientists & Engineers", third Edition, by Douglas C. Giancoli and published by Prentice Hall. Students are required to write a composition about the current chapter each week. The students produce the composition using Microsoft Word. Each composition must have a header that lists the student's name, ID number, date, title of the composition, email address, and page number (page x of y). This is necessary because when printing the compositions they can be kept in order. Students save the first composition with a file name using their last name and the number of the composition (Cruz1.doc) and submit the composition by email as an attachment. It was a challenge to keep track of all the compositions. To help manage the challenge of keeping track of ten compositions and two laboratory experiments for every students, a new email program, Goldmine 5.0 was installed. Goldmine 5.0 provides easy access to the complete work of all the students' compositions and laboratory reports.

To begin the study of physics, students are first asked, "How much is 3 + 5?" Students answer 3 + 5 equals 8. Does 3 meters + 5 centimeters equal to 8? Alternatively, are 3 hours and 5 minutes equal to 8? Are 3 kilograms and 5 grams equal to 8? This opens the topic of units. The fundamental SI (International System of units) units are: for mass a kilogram, for time a second and for length a meter. By using these SI units, the unit for force is a Newton, the unit for energy is a Joule, and the unit for power is a Watt!

In learning about the concept of force, students are first asked to stand and hold their physics textbook in their outstretched hand. The lecture about force continues on to Newton's Laws. When the students put down their books, they are told " pick the book up and continue to hold it in your hand". In the movie, "Star Wars" Obe One Canobe tells Luke Sky Walker to "feel the force!" I ask the students if they feel the force. At this point they say “Yes, Dr Pariser we can feel the force!” Now may we put the books down!

Another aspect of the course involves vectors. Because vectors represent many quantities in physics, (force, velocity, acceleration, momentum), it is necessary to review basic trigonometry. Any vector may be considered the hypotenuse of a right triangle, and then resolved into orthogonal components (the two sides of the right triangle) Students study and construct **“**A GEOMETRICAL PROOF OF PYTHAGORAS’ THEOREM” (1) constructed with a compos and a straight edge. The proof is shown in Figure 1. This was an invited paper presented at the 1999 ASEE by Dr. Pariser.

Figure 1
"A GEOMETRICAL PROOF OF PYTHAGORAS' THEOREM"



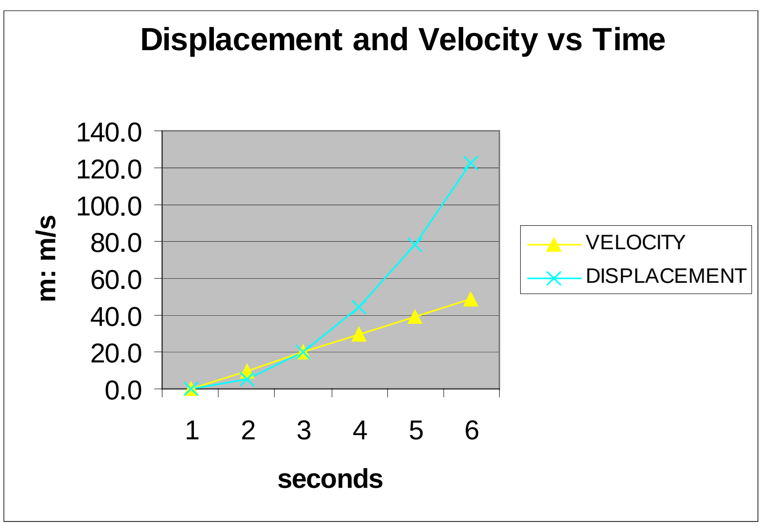
Next, the three trigonometric identities are derived from this theorem.

Students learn to solve displacement problems using Microsoft Excel. A typical problem of examining the displacement and velocity of a free falling object is displayed below. The spreadsheet has four columns: Time, Acceleration, Velocity, and Displacement. By using formulas in Excel, the velocity and displacement of a particle can be calculated (Figure 2). The data can be presented in a graph generated using Excel Chart Wizard (Figure 3)

Figure 2

TIME	ACCELERATION	VELOCITY	DISPLACEMENT
0	9.8	0.0	0.0
1	9.8	9.8	4.9
2	9.8	19.6	19.6
3	9.8	29.4	44.1
4	9.8	39.2	78.4
5	9.8	49.0	122.5

Figure 3



An important dimension of Teaching Critical Thinking is class participation. Homework is also a critical part of instruction in critical thinking. Homework problem numbers are placed on the board and the whole class comes to the front of the room to solve the problems together. It is an interesting sight to see the Professor sitting in a student's seat and the entire class at the board. Students are asked to talk about the problems and to explain the problems to those who are standing by trying to understand. No student sits down until all of problems have been solved. After all of the problems are solved, each student who worked on a problem makes an oral presentation to the class. At the conclusion of the presentations, I go to the board and solve each problem. This insures that each problem has been discussed at least twice and sometimes three or four times.

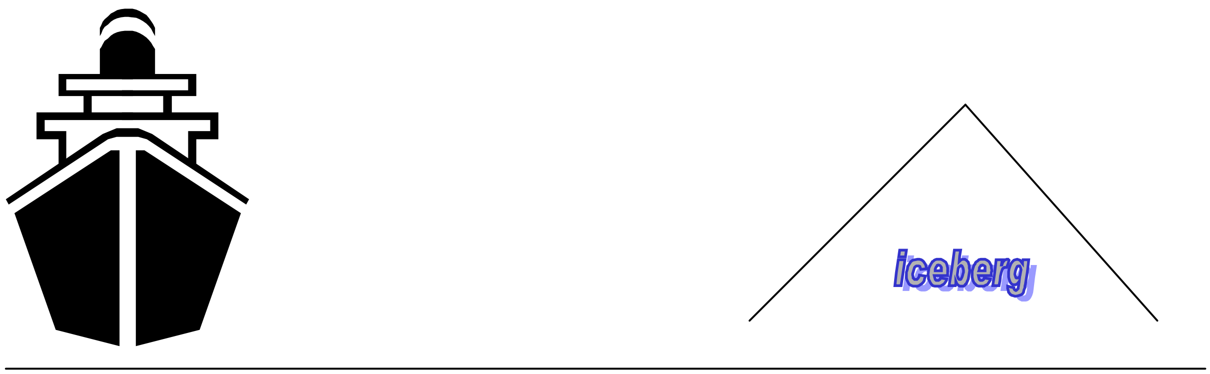
In the laboratory, students are assigned teams based on heterogeneous grouping. To build student self esteem, team names of famous scientists are selected: Einstein, Newton, Fermi, Maxwell, and Joule. The only common language on a team is English. If two students speak Spanish, they are never on the same team. Teams are selected across racial and national lines. After the teams are selected, I ask members to shake hands and to introduce themselves. This is often an awkward moment. I encourage each member to participate and to offer their telephone numbers and email addresses to each other. Each member in the team must collect his own data, and then work together with the other team members to produce a laboratory report. Students receive the format for the laboratory report that is copied onto their computer disk. They copy the format onto the laboratory computers and produce their reports in the laboratory.

The first laboratory experiment involves the use of measuring devices, the vernier caliper and the micrometer. Students are given laboratory specimens and asked to calculate the density of the specimens. What is this cylinder made of? Students will often ask. I answer, calculate the density, and then look up that density in a handbook and then identify the specimen. When questions arise in the laboratory, I tell students to ask their team members before they ask me. After each person on the team has presented his opinion, I then present my explanation.

Vl Creativity in testing

Students are given a challenge. Create a problem for the next examination, solve the problem, and submit by email. I offer a 25 point bonus if I use the students problem on a test. They may not submit homework problems. Students go to the library, read other physics textbooks, and submit very creative problems. When the examination is produced, I place the student's initials or name into the question. There is a sense of pride when students see their problems on the examination. I was very pleased with the creativity of the problems submitted. Some students enhanced the problems by drawing a picture using Microsoft Windows Paint and pasting it onto their problem! Two examples of problems submitted by students are presented in Figure 4, and Figure 5.

Figure 4

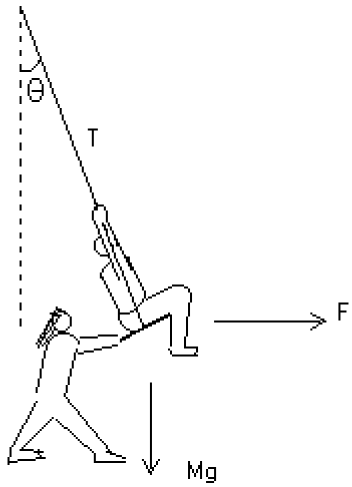


The 70-ton *S.S. Thomas* is sailing across the north Atlantic at a speed of 25 knots. An iceberg is spotted 2000 feet ahead. The ship's captain orders the crew to stop the engines, and then reverse the engines. At the *S.S. Thomas's* current speed, the ship will come to a complete stop in 45 seconds. A) What is the ship's momentum before the engines are stopped? B) Will the ship stop in enough time in order to avoid colliding with the iceberg? (Submitted by ST)

1 metric ton = 1000 kg
1 knot = 1 nautical mph
1 nautical mile = 6080 ft
1 meter = 3.28 ft

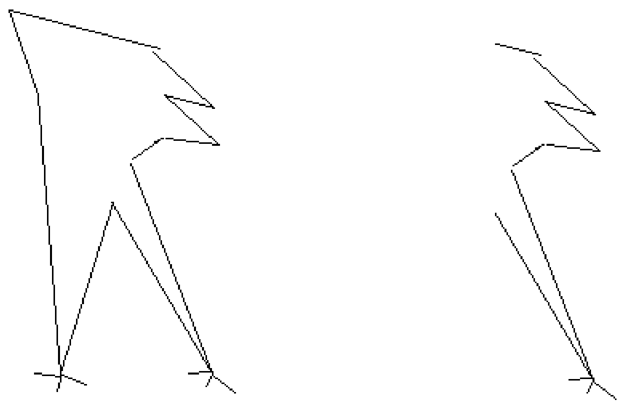
Figure 5

A child of mass M sits in a light swing suspended by a rope of negligible mass. His sister pushes him forward by a horizontal force until the rope makes an angle θ with the vertical. What is the tension in the rope and how much horizontal force is required to hold the child in that position? (Submitted by WKC)



I usually give a bonus question during the first examination. If a chicken and a half costs a dollar and a half how much would three and a half chickens cost? The answers often bring a smile to my face. On a review of the examination, I draw a funny looking chicken and then draw what appears to be half a chicken (Figure 6). I label one chicken, 1 dollar and half a chicken, ½ dollar. So three and a half chickens costs 3 and ½ dollars. Everyone smiles but they begin to see the creative value of drawing pictures to solve problems.

Figure 6



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V1 Student Feedback and comment

The students offer feedback on the conclusion paragraph of the laboratory reports. Overwhelmingly the students vocalize approval and spend countless hours looking for creative problems in the library and discussing physics with other team members. This is a quote from the conclusion of Experiment 1 “Measurement, Statics, And Mechanics” preformed by the Fermi Team.

“What we learned during this experiment was how to measure mass, length, and thickness with various tools. We also learned how to use the measurements we got to find the density of an object. Besides learning the important applications of the principals of physics, **we also gained valuable experience working together with people we might not have chosen to work with if given the chance.”**

V11 Academic Outcomes

Course grade is based on the three tests, a final exam, and a passing grade in the laboratory and class participation. Class participation includes attendance, homework questions and answers that are carried out during the class period. Each week students are required to write a composition about the chapter.

Tests	30%
Final Exam	40%
Class Participation	30%

The academic performance for our class is shown in the table below:

A	3
B	7
C	2
D	0
F	0
INCOMPLETE	2

V11 Summary

This paper discusses the challenge of teaching critical thinking to electrical engineering technology students. The presentation is to integrate critical thinking into the curriculum and to emphases the opportunities in lectures, laboratories, homework, and examinations. The success of the students is quite encouraging and the progress in self-assertiveness, confidence and oral presentation is gratifying. The outcomes of entering four-year college programs and corporate America are being compiled.

Acknowledgements

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References

1. Pariser, Bertram **"A GEOMETRICAL PROOF OF PYTHAGORAS' THEOREM**" invited paper presented at 1999 ASEE Session "3365 Class & Distance Educ./Math, and Engrg."

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