Introductory Maximizing Engineering Potential Course

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abstract
An introductory engineering course has been designed and successfully implemented to introduce underrepresented minority students to a systematic strategy of problem solving. A faculty/MEP staff team reinforces the lecture by facilitating a creative problem solving recitation. The course uses a strategy of systematically question answering to challenge fundamental mathematics and physics problems. The course also introduces the students to college success skills. The course culminates in a heterogeneous team based project. The students are introduced to a generic project planning strategy that focuses on goals, methodology, timelines and work distribution among personnel. Team building exercises are used to establish team norms and to demonstrate the synergistic advantages of a collaborative project. An inexpensive project, which involves engineering measurements and estimation, is selected to challenge the student's creative skills. The project culminates in a final written report. The course utilizes a combination of instructor (50%) and peer based(50%) evaluations that provide feedback and stimulate individual performance. Peers are asked to identify results achieved by all team members. In addition a continuous improvement format is used to quantitatively evaluate an individual in four performance areas. Explanations must be provided for all ratings, i.e., why is a rating high and if a rating is low a suggestion for how to improve must be provided.

background
Engineering Orientation (EGR110) was developed as the introductory course for Cal Poly Pomona students participating in the Maximizing Engineering Potential (MEP) program. The course focuses on problem and engineering analysis and success skills for first time university students. The MEP program was initiated in 1983 as "an academic enhancement program for over 650 African American, Latino, and Native American students in Engineering and Computer Science. The program's purpose is to increase the number of students who graduate from these technical disciplines."(1)

Although this paper will describe the EGR110 course, particular emphasis will be placed on the use of pedagogical strategies for problem analysis and a group project.

description of course
The EGR110 course is required of all first year MEP students at Cal Poly Pomona. It is a 3 unit course that is taught in an academic quarter. During the fall quarter of 2000 a student population of approximately 110 participated in a weekly 75-minute lecture

which utilized some active learning strategies. The lectures were presented in a smart classroom and all lecture slides were posted on the course Web site. The class also included a 75-minute activity session which had a student population of 25-30. A team of four faculty met regularly to plan the activity sessions. This team selected the two required texts by Eide, Jenison, Mashaw and Northup (2) and Donaldson (3) to support the course material.

The educational objectives for the course are summarized below:

1. Use a Systematic Method of Solving a Broad Range of Engineering/Science "Word" Problems,
2. Efficiently collect, represent and correlate experimental/plant data,
3. Understand and apply the concepts of significant digits, accuracy, precision, errors and approximation ,
4. Understand different systems of measurement and conversion from one basis to another,
5. Proactively master the Cal Poly Pomona bureaucracy,
6. Develop skills that are essential to optimizing your collegiate performance, e.g., study methods and time management, and
7. Appreciate the benefits of the team approach to accomplish a project and work effectively as a member of a team.

Most of this course material was supported by the two required texts. In addition to lecture slides, course handouts and problem, quiz and exam solutions were posted on a course Web Site. The course requirements were rather demanding since students were evaluated based on performance in quizzes, two major exams, weekly class assignments, MEP support activities, a major project report and a final exam.

problem analysis

The author has been teaching engineering students for almost thirty years. During that time he has noted that many students find it easier solving mathematically formulated problems but they struggle with "word problems." Their major challenge therefore involves transforming the word description of a problem into the mathematics domain.

The author has became familiar with the work of Richard Paul (4) who offered strategies for introducing reasoning and critical thinking in the classroom. Paul proposes eight elements of reasoning: "…Purpose, Question at Issue, Information Element, Interpretation and Inference, Concepts, Assumptions, Implications or Consequences, and Point of View..." Paul then transforms these elements into a series of questions. These questions include: "…What is the purpose? What exactly is the question? What information are you using? How are you interpreting that information? What concepts might account for the way in which this information is interpreted? What are your underlying assumptions? If that is what you want, what are the implications? What would a person with different background say if they heard you?…"

Based on Paul's logic one may evolve a series of questions whose answers should facilitate the solving of engineering word problems:

What is the system? For most situations the answer to this question is a sketch. In many cases this drawing aids the problem solver in developing a clearer understanding of the problem through visualization.

What are the inputs and outputs? This requires the problem solver to examine the problem statement and to categorize the information provided as inputs (knowns or givens) and outputs (unknowns). Efficient communication of this information is facilitated by drawing a rectangle and labeling it model. One then draws a series of labeled input and output arrows.

What is (are) your system model(s)? This is the most challenging question because it requires writing relationships (mathematical formulations) that indicate how the system outputs are functions of the system inputs. However, this step is most definitely facilitated by examining the answer to the previous question.

What are your assumptions? This question is important because whenever one writes a mathematical relation for an engineering system there are usually accompanying assumptions, e.g., steady state, V-L equilibrium, Newtonian fluid, etc. If one changes the assumption(s) then the model(s) change(s). This occurs for many real engineering systems because more complex models must be used to adequately explain real data, e.g., unsteady state, non V-L equilibrium, and nonNewtonian fluid.

What are the system transport and physical properties? The model(s) will include these properties but their values must be obtained from handbooks or derived from experimental measurements. The problem solver is further challenged when these properties are not readily available. In such cases there are definite advantages to using estimates of the properties and then determining the sensitivity of the model results to these estimates.

What is your strategy for solving your model? At this stage one is working in the mathematical domain. During this step one is not solving the model but initially analyzing the model to determine if a solution exists. Often the model will have more unknowns than equations. This indicates that there are degrees of freedom that the problem solver is at liberty to specify. If the solution of the model exists the focus is now on how do you solve it. This step may be simple if the model may be explicitly solved for a single unknown variable. However, the computational process may be more complex if the model involves an implicit function or systems of linear or nonlinear equations.

What is (are) the numerical answer(s)? This will involve solving systems of either linear or nonlinear equations. This step will be most definitely be facilitated by the use of software tools like Matlab and Excel. The problem solver must remember to include the correct number of significant figures and units with the answer.

Is the answer reasonable? This is an important but challenging question for problem solvers with limited experience. It may be aided by comparing the model answer to the value obtained for a simplified model.

Some students object to this problem solving method because it is too time consuming. These students may have developed their own method which may be more efficient. It is therefore best to challenge students with problems that have a range of difficulty to confirm that other systematic problem solving strategies are also effective. The required EGR110 text by Eide, Jenison, Mashaw and Northup provided a range challenging algebraic and trigonometric type problems. However, it was discovered that some of the students in EGR110 were deficient in trigonometry. For these students the author found a reference by Meyer and Sallee (5) to provide problems with a range of algebraic complexity.

class project

The biggest challenge to both the course facilitators and the students was a team based (3-4 students per team) project. Heterogeneous team's were assigned based on course to date performance. The project goal was to determine the cost of the paint required to coat the external surface of a large concrete building on the Cal Poly Pomona campus. After assigning the project the students were introduced to both team building and project planning.

The students next participated in a discussion about effective teams. Hirschhorn (6) defined an effective team based work environment as one in which there is individual initiative, group authority, members learn to collaborate and communicate thoughts and feelings. Tjosvold (7) describes the team as the basic building block of the organization and it is important to encourage genuine and open relationships. Some of the characteristics of a good team include: informative and comfortable environment, participative discussion, attentive listening, consensus decision making and freely expressed ideas.(8) Therefore, the teams were next challenged to develop a team identity (name and logo) and a set of team norms. These were drawn on poster paper and presented during an activity "walk and talk" session.

Rather than have the students proceed aimlessly with the challenge of a team based project they were introduced to project planning. This involved focusing on the what, how, who and when of a project. The teams were then challenged to develop a list of tasks that needed to be accomplished, a schedule for these tasks and the assignments for individual team members. Teams were required to author written project plans that addressed all of the above issues. Teams were also encouraged to use Gantt charts to clearly communicate project tasks and the schedule for these tasks.

Although the team project consumed considerable time and effort the positive energy in the class heightened during this stage of the course. The teams used various resources to estimate the buildings surface area: building blue prints and actual building

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measurements. The teams then consulted with painters and paint suppliers to determine the type, amount and cost of the paint.

With any team based project there are problems with team member roles and equitable distribution of the project work. To deal with these issues it was decided to empower the teams by using peer based performance reviews. Therefore, 50% of an individual's rating was based on the team's final project score and 50% was based on the composite rating of an individual's performance by their peers. Each member of the team was therefore evaluated confidentially by each of their peers in the following categories: resourcefulness (20%), results quality(40%), contribution to team (20%), and quality of communication (20%). Each of these four criteria were defined for the students before the peer reviews were implemented. The resourcefulness criterion was the most difficult to understand. It was therefore defined as "this criterion refers to one's ability to deal skillfully and promptly with new situations or difficulties."(9) It was also noted that this characteristic also addresses how adept the individual is at solving problems the team needs to have solved. An individual may be resourceful even if s/he does not solve a problem by oneself but is very successful at identifying and utilizing outside resources.

The peer ratings were quantitative (1(needs significant improvement) – 6(met expectations)) and required a written explanation. Because of an emphasis on continuous improvement low ratings required suggestions for improving one's performance in particular area. High ratings had to also be explained. The results of these peer ratings were summarized by the course facilitators and then returned to students during brief one on one performance review sessions.

Because of the limited report writing experience of the students the course facilitators found it necessary to provide guidelines for the final project reports. All final reports were to clearly describe the project goal, methodology, results, conclusions, and references. It was also necessary to return the reports for one rewrite because of the lack of raw data and insufficient explanation of how results were obtained.

student evaluations

The students completed an assessment of the performance of the course instructor at the end of the academic quarter. Performance was rated in 24 categories and students used a 1(very good), 2(good), 3(satisfactory), 4(poor), and 5(very poor) rating scale. The performance summary appears in the table below:

Instructional Assessment/Lecture Evaluation

Category	**Rating**
Discusses recent developments	2.65
Emphasizes conceptual understanding	2.29
Explains clearly	2.59
Is well prepared	1.65
Gives lectures that facilitate note-taking	2.18
Summarizes major points	2.18
States objectives for each class	2.29
Identifies what s/he considers important	2.41

Instructional Assessment/Lecture Evaluation

Category	Rating
Encourages class discussion	2.59
Invites students to share their knowledge	2.76
Knows if class is understanding him/her or not	3.12
Has students apply concepts	2.75
Shows genuine interest in students	3.06
Gives help to students having difficulties	2.76
Relates to students as individuals	3.18
Is accessible to students out of class	2.12
Has an effective style of presentation	2.41
Concerns for the quality of his/her teaching	2.29
Motivates students to do their best work	2.53
Gives interesting & stimulating assignments	3.06
Realistically assesses student understanding	2.18
Keeps students informed of their progress	3.41
Overall teaching effectiveness of instructor	2.65
How worthwhile was the course	2.88
Average Rating	**2.58**

The overall teaching performance was effective because 19 of the 24 categories were rated in the (2)good to (3)satisfactory range. Only five categories (knows if class is understanding, shows genuine interest in students, relates to students as individuals, gives interesting and stimulating assignments, and keeps students informed of their progress) were in the satisfactory to poor range. Part of the lower ratings might be attributable to error on the part of the instructor regarding the assumed mathematics background (competent in trigonometry) of the students. Because this was identified early in the course a 2-3 hour trigonometry review session with handouts was offered for the class but less than 10% of the class attended. Therefore, after the first 2-3 weeks of the course the mathematics focus switched to algebra. The rating table indicates that the students wanted the instructor to show more interest in them and to relate more to them as individuals.

observations

The EGR110 (Engineering Orientation) at Cal Poly Pomona was a challenging experience for both the course facilitators and the students. Although performance data is not available the instructors strongly feel that the students benefited from being introduced a systemic problem analysis methodology and the process of successfully challenging a team based project. Furthermore, the team project experience was facilitated by the use of peer performance reviews.

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