AC 2011-1527: TRANSITIONING STUDENTS TO THE WORKPLACE IN AN ACADEMIC SETTING

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Abstract: In their collegiate studies, students are given a wide array of concepts, theories and equations to assist them in their future endeavors. However, students entering the workforce are often not prepared for the soft skills necessary to succeed in the workplace. Additionally, students have not been sufficiently exposed to practical critical thinking methodologies that will benefit them as they encounter open-ended problems that can be conveniently answered using a few equations. A course developed at the University of Michigan exposed upperclassmen undergraduates in a wide range of engineering majors to a vast array of ideas to develop their creativity, to enhance their problem solving abilities and to make them aware of issues they will most likely confront in the workplace. The use of real-world examples, guest lectures from industry and a course project allowed students to directly apply the problem solving heuristic discussed in lecture and recognize that these concepts are not solely academic and can be used in their daily lives. Initial feedback from the students has indicated that the students have improved their abilities in teamwork, time management and communication skills, skills crucial to a professional engineer, but often underemphasized in academic settings.

Introduction: Students are given the opportunity to learn the essentials of chemical engineering and to begin to develop their closed ended case based problem-solving skills, writing abilities and oral presentation skills. However, many problems facing students in classroom settings are limited in scope, an issue magnified by the dramatic shift and broadening of scope seen in the job expectations of chemical engineers over the past 30 years.[1-3] This shift has required chemical engineers to be integrated with a large number of different fields such as materials science, electrical engineering, biology, chemistry, physics and business. This integration has made it crucial for chemical engineers to be capable of communicating effectively in multidisciplinary teams.[4] Therefore, it is crucial for future engineers to be able to foster and develop their creative and critical thinking skills and to have an opportunity to work with different mindsets and skill sets on complex, real-world problems.

Students absorb a vast skill set from work completed both in academia and from any external experiences such as an internship or a co-op. However, these experiences typically do not expose students to a litany of issues that they will face once they enter the workforce. Typical questions that an employed young engineer can face include: How should I invest my money? What issues will I face now that my work has sent me to a foreign country? How do I negotiate and when is it acceptable to negotiate? How do I create my own company? Although an academic course is unable to address all of these issues in an in-depth manner, exposure to these and other non-technical issues will be of great benefit to students.

To address these voids in student knowledge, a 3 credit hour course at the University of Michigan at Ann Arbor, entitled *Problem Solving, Troubleshooting, Entrepreneurship and Making the Transition to the Work Place*, was created to address some of these aforementioned issues. The course was first offered in the fall semester of 2006 and has been offered subsequently in the fall semesters of 2007, 2008 and 2009. Because of sufficient cross-departmental advertising, the course has annually enrolled approximately an equal amount of chemical engineers and non-chemical engineers, primarily industrial engineers, but students from materials science, aerospace engineering, electrical engineering and mechanical engineering have also enrolled in the course. Enrollment for the class has been in between 20 and 30, generally an even mix of juniors and seniors.

The course meets twice a week for ninety minutes. The main components of the course are lectures/discussion, in class problems, homework problems and a term project. The two major goals of the course are to: (1) develop and enhance critical thinking and creative problem solving skills and (2) prepare students for the workplace. A brief syllabus noting the topics of the course is shown in Table 1.

Week	**TABLE 1: Course Topics by Week: Topics to help prepare students for specific workplace issues are in bold. Topics presented by guest lecturers are italicized.** Topics
1	Introduction, Developing a Right Frame of Mind to Solve Problems, Team Skills, Creative Skills
2	Defining the Problem, Gantt/Deployment Chart, Creative Skills
3	Problem Solving on the Job, *Developing a Survey*
4	Defining the Problem, Kepner Tregoe (Problem Analysis, Situation Appraisal), Creative Skills Exercise
5	***Voice of the Customer, TRIZ, Entrepreneurship***
6	Kepner-Tregoe (Decision Analysis, Potential Problem Analysis), Implementation, Evaluation
7	Midterm Project Presentations (Status Reports)
8	Fall Break, **Ethics**
9	**Negotiation Skills,** Having a Vision
10	**Negotiation Skills, *Financial Planning***
11	***Time Management[5], Cross-Cultural Communication***
12	***Entrepreneurship***
13	***Gender Issues in Engineering, Proper Decorum in the Workplace***
14	Final Project Presentations

These areas are explored using the following means.

Problem Solving Lectures: Creative problem solving skills are developed using the problem-solving heuristic outlined in the text *Strategies for Creative Problem Solving* by Fogler and LeBlanc, whose origins are derived from the McMaster Five-Point Strategy.[6,7] The heuristic will be described in more detail later.

Group Problems: Students complete an in-class problem at the end of lecture to immediately apply the tools learned in the particular lecture. Out of class problem sets are assigned to further enforce the concepts discussed in class. Primarily, the out of class problem sets are completed in teams of 3 or 4. The teams work together throughout the semester and are assigned based on final project preference and ensuring that no group contains more than two students from a particular major.

Guest Lectures: Lectures dedicated to specific topics regarding the workplace are primarily given by members of the industrial sector. Their lectures address topics such as entrepreneurship, financial planning, cross-cultural communication and gender issues in engineering. Although many of the guest lecturers have a background in chemical engineering, all lectures are presented to engage a general engineer. As applicable, some of these lectures involve exercises that the students must complete either before or after the lecture. For example, a lecture on entrepreneurship requires the students to develop a 30 second elevator pitch to a job recruiter.

Term Project: The objective of the course project is to give the students the ability to apply the problem solving heuristic in teams to a particular business or organization. Each team is required to carry out the analysis presented in Table 2 for their business:

TABLE 2: Objectives for Term Project
1.) Define or uncover a number of problems, both spoken and unspoken. 2.) Generate a variety of solutions for each problem. 3.) Carry out an analysis to choose the best solution for each problem. 4.) Carry out a potential problem analysis for each solution generated. 5.) Propose an implementation plan. 6.) Evaluate each step of the project.

Table 3 provides a list of businesses and organizations that agreed to be part of the course projects. The companies/organizations allow students to interview and conduct surveys with employees and in some cases customers. Generally, all groups are willing to assist the students in obtaining the necessary information without being too obtrusive. This accessibility gives the students an opportunity to fully explore the problems they found without repercussions from upper management.

TABLE 3: Businesses and Organizations Involved in Term Projects
Ace Barnes Hardware
Bella Vino (upscale beer/wine/food)
Gross Electric (industrial/commercial lighting)
Panera Bread
University of Michigan dormitories (multiple projects)
Zoup!

The major deliverables for the project are a midterm status update and a final presentation and report. The status report is used as a tool to check on the progress of the groups to ensure they are on track to complete their projects and to have them assess the potential problems they might face when finishing their project and determine appropriate contingency plans. The final presentation consists of a 25 minute presentation highlighting the key results and their usage of the techniques acquired in the class and a 20 minute question and answer session where questions were asked by the instructional staff, the students and in the third year of the course a four-member industrial panel. The guest panel consisted of individuals with a wide breadth of industrial experience and greatly enhanced the quality of the question and answer portion of the presentation with their unique, less academic perspectives.

Problem Solving Heuristic: The problem solving heuristic that the students use can be broken down into five separate sections: problem definition, solution generation, deciding a course of action, solution implementation and solution evaluation. Figure 1 shows a schematic of the heuristic.

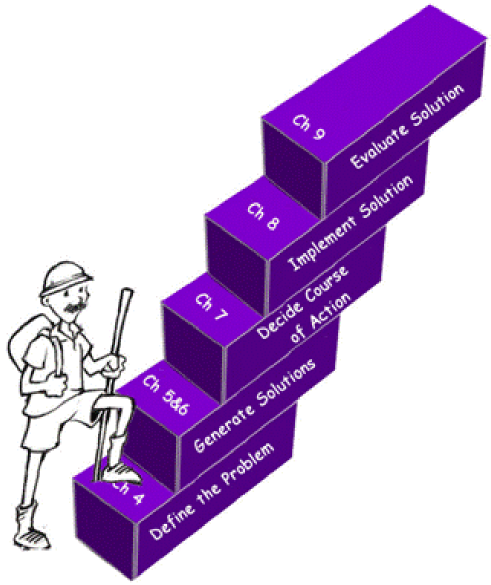

Figure 1: Schematic of the Problem Solving Heuristic[6]

Problem Definition: When employees in government, industry and academia were asked to define the biggest problem faced in solving problems, a majority said defining the problem. From visiting many chemical and oil companies, a number of examples were collected where the perceived problem was defined and attempted to be solved.[6] The major issue faced when solving a perceived problem (or symptoms of a problem) is that it is often incorrectly defined or too narrowly defined, which artificially reduces the number of possible solutions and can even eliminate the most viable solutions. For example, the Bureau of Engraving and Printing in 1990 attempted to remedy the smearing of ink on the new paper money.[6] The initial problem statement was "Develop a program to find better printing inks." After spending significant time and money to research programs to develop a program to find better printing inks, the Bureau realized that the real problem was not with the inks but the new printing machines, which were applying insufficient pressure onto the new type of paper to allow for the ink to settle inside the paper. If the initial problem were more broadly defined as "Find out why the ink was smearing.", the possibility of an issue with the printing machines would have been available in the initial solution generation and the money used to find better printing inks could have been more effectively utilized.

To help the students and future engineers to define the real problem, a number of techniques are presented in the course and used in in class problems and/or problem sets. The first steps in understanding and defining the real problem are involved in obtaining information and are presented in Table 4.

TABLE 4: First Steps in Problem Definition[6]
1.) Collect and analyze the appropriate data
2.) Talk with people who are familiar with the problem
3.) View the problem first-hand (if possible)
4.) Confirm all findings and continue to gather information.

During this process, it is crucial to ask critical thinking questions that can uncover the real issues that are being faced. Once the information has been gathered, an initial problem can be developed and then refined using a number of techniques shown in Figure 2 and discussed below.

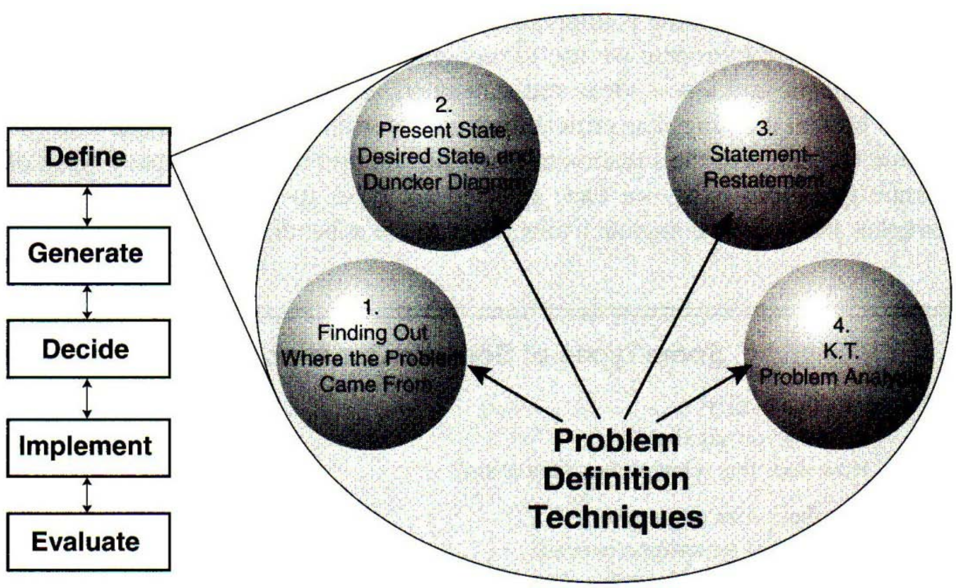

Figure 2: Problem Definition Techniques[6]

1.) *Finding out where the problem came from* uses Socratic questioning and critical thinking to ferret out the real problem.

2.) *The Duncker diagram* can be used to broaden a problem statement by determining perfectly viable solutions to the problem that may not satisfy the currently defined desired state.[8]

3.) *The statement-restatement technique* helps refine the original problem statement.

4.) *Kepner-Tregoe (K-T) problem analysis* uses the four dimensions of a problem: what, where, when and extent and uses critical thinking to determine distinctions between what the problem is and what the problem is not.[9]

For their projects, students can determine the appropriate problems facing their organization by interviewing relevant people, conducting surveys and making on-site visits.

Solution Generation: Once the proper problem has been identified, the next step is to come up with a number of potential solutions to the problem. Even if the problem is accurately defined, many solutions may not even be considered or thought of because of the mental blocks that people have developed. By making students aware of these blocks: conceptual, perceptual, emotional, cultural, environmental, intellectual and exposing them to methods to overcome these blocks, they are more open to generating a wider range of solutions, no matter how improbable the solution may sound.[10,11] Students are then introduced to a broad set of solution generation techniques that take advantage of a number of different thinking processes beyond typical free association used in brainstorming. The use of Osborn's checklist (vertical thinking) allows students to add new ideas by doing such things as modifying, magnifying and rearranging a particular part of a problem.[12] Techniques to promote out of the box and lateral thinking, such as random stimulation words and using other people's views are introduced in the course as a practical means to generate ideas.[11] These and other lateral thinking techniques along such as futuring, analogy, cross-fertilization and TRIZ, help the students think out of the box to develop further ideas.

Deciding a Course of Action: Once the actual problems have been identified and many solutions for each problem have been developed, the next step is to determine which problems are most important and which solution is most viable. The students are introduced to the work of Kepner and Tregoe, who developed a systematic approach in assessing the most pressing problems and the most viable solutions.[9] The four components of Kepner-Tregoe are shown in Figure 3.

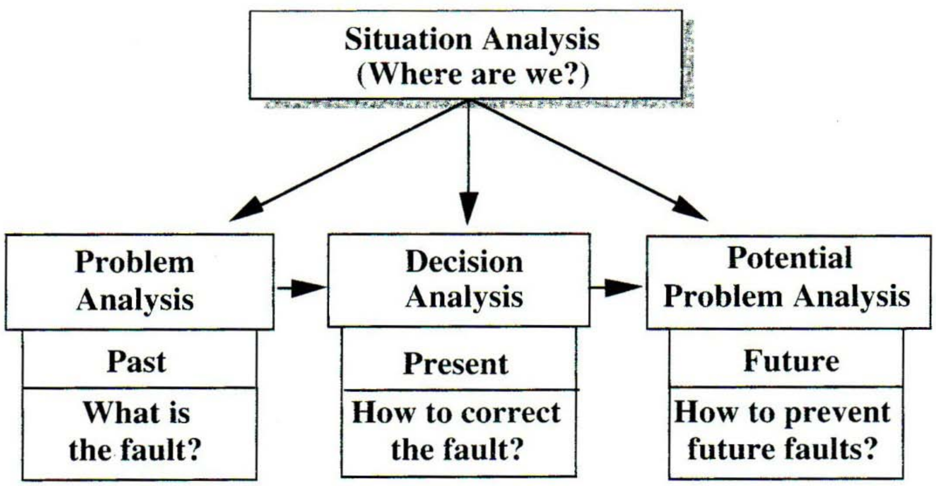

Figure 3: Components of Kepner-Tregoe Analysis[6,8]

1.) *Situation Appraisal:* Situation appraisal helps to decide which problem and process and evaluates all the problems by three criteria: timing (the immediacy of the problem), trend (the evolution of the problem over time) and impact (the seriousness of the problem). The evaluation allows students to determine which problems are most important and which problems their project would encompass, dependent on time and financial resources. It also helps assess what the next step is: whether that is finding the problem (PA), making a decision (DA), or identifying potential problems (PPA).

2.) *Problem Analysis:* Problem analysis was discussed in detail earlier in the problem definition section.

3.) *Decision Analysis:* Decision analysis is a systematic approach used to determine which of a number of generated solutions best solves a problem. From their knowledge of the problem through the information gathering process, the students are able to break the objectives that the solution needs to address into two categories: *musts* and *wants*. Any solution that does not satisfy all of the musts is immediately rejected as an infeasible solution. The wants are valued and scored for each alternative solution to arrive at the best solution. Finally, the adverse consequences of the solution are assessed and evaluated based on their importance and how likely the adverse consequence will occur for the solution.

4.) *Potential Problem Analysis:* A potential problem analysis is conducted to ensure the success of the solution by analyzing what could go wrong with the solution and how to handle it. This process is developed by brainstorming to identify the potential problems, finding their possible causes, determining a preventative action and finally developing a contingency plan if any of the potential problems come to fruition. ‘

Implementing and Evaluating the Solution: Because of the time constraints of the course, it is unfeasible to complete a thorough implementation and evaluation of the solutions for they are not fully developed until the end of the course. However, some of the tools used for solution implementation are discussed and are used by students as guideposts for completing the project. The concepts of a Gantt chart, a deployment chart and a budget are presented to allow the students to structure their course project and to assure that tasks were being completed and appropriately divided among the group members. Additionally, groups are expected to explain how they expected the solutions to their problems to be carried out and what follow-up procedures would need to be completed to evaluate the overall success of the solution.

For the scope of the work completed in the class, the evaluation step acted as a sanity check to ensure that the group's proposed solutions made sense. The three major issues discussed to assess in the evaluation stage are whether the solution (1) solves the problem completely, (2) is safe and (3) is ethical.[6] For the problems the students analyzed, safety and ethics were generally not of great significance for the solutions they provided. However, it is important to make students aware of these issues when analyzing situations, particularly engineering ethics, a topic generally not discussed in great detail in the chemical engineering curriculum. Table 5 shows how the heuristic was used for a term project completed in the course.

TABLE 5: Usage of the Problem Solving Heuristic to Solve a Real-Life Problem. This group was asked to: "Determine the problems employees have at a bakery-café in a college town. Analyze the problems you uncovered and then generate and evaluate solutions for each problem. Finally, pick the best solution for each problem you identified." (The information presented here represents only a portion of the work completed.)
Problem Definition: Information was gathered by interviewing the manager using critical thinking questions and conducting employee surveys (22 out of about 30 employees responded). The bakery-café was visited during dinnertime to observe of both the employees and the customers. From this information, three major concerns were identified: (1) Bottlenecks occur because of insufficient staffing. (2) Co-workers do not take responsibility for their tasks. (3) Employees do not receive enough training for their tasks. Brainstorming techniques were utilized to develop the survey. The statement-restatement technique and Duncker diagram were used to ensure that the problem definitions were addressing the real problem.
Solution Generation: Both lateral thinking and vertical thinking ideas were used to generate solutions. For example, for problem (3), ideas such as have practice runs before opening, employee tests, assigning fellow employees as trainers and making work instructions present and in plain view at each workstation were all suggested.
Deciding a Course of Action: A K-T situation appraisal was done on the three problems to determine which problem was most important. Problem (2) was viewed to be the most

pressing problem followed by (1) and (3). The group decided that they were able to evaluate and analyze all problems for their project. Problem (1) was further investigated by using a potential problem analysis. Solutions to handle this problem include a task checklist and rewarding employees for their work. The group realized that both initiatives could be implemented at the same time and made that recommendation. Problem (2) was further investigated using a decision analysis. Four solutions: hire more workers, purchase more equipment, transfer workers between shifts and early shift preparation. Their analysis led them to the suggestion that purchasing additional equipment would be the most viable solution.
Implementation: The implementation of the results to Problem (1) will be carried out by created laminated sheets with the appropriate tasks on them. If issues continued, employees would be required to initial the sheet when the job was completed. Another idea developed was the concept of a "check-out" employee who would make sure that all of an employee's tasks were completed before an employee could leave.
Evaluation: To determine employee satisfaction with the changes, short surveys or interviews could be conducted by the group (or a set of people not affiliated with the management). Most of the evaluation of this will be readily seen by managers on a day-to-day basis.

Student Feedback: The course has evolved based on the thoughts provided by the students at the end of the semester. The end of the course survey consists of two parts: (1) four questions asking for their general thoughts on what they liked and disliked in the course, advice for future classes and the most important things the students learned in the course and (2) four questions asking for what they learned in the areas of problem solving, completing their project, teamwork and communication. The results from some of these questions can be found in Table 6.

TABLE 6: Responses from In-Class Student Feedback. The number in parentheses represents how many students noted this issue or something closely rated (N=45, the 2006 and 2008 classes)
Q: What advice would you give to next year's class? "Start early with the project and set up regular times to meet with your group." (32) "Outside of class, think about situations or other classes you could apply the material: you'll surprise yourself." (18) "Go to class everyday and pay attention and take notes. The real detriment will be to your personal experience if you don't." (17) "Take advantage of the guest lecturers and ask questions." (7) "Mention that you've taken a problem solving class in any interviews you have and you'd be surprised how impressed people are when you can explain a Kepner-Tregoe decision analysis." (1)
Q: What are the most important things you have learned from the course? (Students were asked to provide their top four choices. The total below represents the number of students that had this topic

in their top four.	
Kepner-Tregoe Analysis (40)	Negotiation (14)
Creative Thinking (22)	Problem Definition (13)
Teamwork (22)	Communication Skills (8)
Financial Planning (15)	Cultural Differences (4)

An interesting trend that has been seen is the divergent tastes of the students, primarily for the information presented in class that was not directly related to the problem solving heuristic. A particular topic of interest for some students was a topic other students believed should be eliminated from the course and vice versa. Although only briefly discussed in the course lectures, the concepts of teamwork (particularly how to handle group conflicts, how to appropriately distribute the workload and how to interact with fellow group members) time management and communication skills came through as lessons the students gained by taking the course.

Industrial Feedback: Although a quantitative study has not be conducted from the industrial setting, initial reviews from guest lecturers regarding the course have been very positive. Lecturers have commented positively on the uniqueness of the course and that the tools learned in the course can be a great asset for both job interviews and in the workplace. Additionally, a recruiter spoke to the AIChE student chapter and encouraged students to take the course because of its utility in industry.

Conclusions: A new course developed at the University of Michigan exposed upperclassmen undergraduates in engineering to a wide number of ideas to develop their creativity and their problem solving abilities and a number of issues they will confront as they transition into the workplace. The use of real-world examples and a course project allowed students to directly apply the problem solving heuristic discussed in lecture and recognize that these concepts are not solely academic and can be used in their daily lives. Feedback from the students indicated that in addition to learning the course curriculum, they developed their abilities in teamwork, time management and communication skills, skills crucial to a professional engineer, but often underemphasized in academic settings.

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