



**THE TEACHING OF ELEMENTARY
PROBLEM SOLVING IN
ENGINEERING AND RELATED FIELDS**

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PATTERNS OF PROBLEM SOLVING - A CAMPUS-WIDE COURSE AT UCLA

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ABSTRACT

Patterns of Problem Solving is a four-unit course offered in twelve sections each quarter of the academic year. The course discusses tools and concepts useful in problem solving with a balance sought between modeling techniques and attributes of human problem solvers. Problem solving is presented as a dynamic open-ended process encompassing diverse academic disciplines.

The course is sponsored by the School of Engineering and Applied Science at UCLA, but it has an appeal to students campuswide. The more than 4000 students who have taken the course represent more than thirty major fields of study and all levels at the University from freshmen to graduate students. The students have repeatedly rated the course as an outstanding educational experience that helped them consolidate past experiences and set the stage for easier assimilation of subsequent learning.

The diversity of both student backgrounds and the course subject matter led to the development of a unique peer teaching program. The peer teachers are a link between the instructor and the students, providing assistance to students and feedback to the instructor. This makes it possible to maintain continuity in classes with students of diverse backgrounds and interests. Peers and instructors are available daily in the course learning laboratory for consultation with students.

BRIEF HISTORY

Patterns of Problem Solving was developed at UCLA and offered for the first time in the fall of 1969 to a class of thirty-two students. It was announced as an elective campuswide interdisciplinary course. By 1973 the course grew to three sections per quarter with an enrollment of 250 students for the year. The steady state enrollment in 1976-77 reached 1600 students, with twelve sections of the course

offered each quarter and two sections in the summer session.

As enrollments kept increasing, a special peer program was introduced in 1974. Peer teachers are outstanding students who have completed the course and undergo an extensive summer training program to prepare them for their role. For the past three years the peer program has stabilized in the number of peers and their duties. Generally, there are two peers per course section. The peer teachers are available in the course learning laboratory to assist students and provide the instructors with important feedback. Peer teachers are paid for eight hours per week although they often put in much more time on their own. The involvement of the peer teachers in the learning process makes it possible to conduct classes for students with diverse backgrounds and interests and maintain a continuity that is otherwise difficult to achieve. The peer program makes assistance available to the students at all times with no need for appointments, and reduces the demands on the time of the instructors.

Sections of the course have been taught by faculty members from different disciplines, such as Engineering, Psychology, Law, Business, Philosophy, Architecture, Mathematics and Computer Science. These faculty members are outstanding teachers and have been noted for their diverse interests. Some instructors are recruited, others offer to teach the course as an extra load and consider the undertaking a valuable educational experience. Since it is not possible to cover the thirty-eight sections of the course offered each year with professors only, they are joined by outstanding teaching assistants who are trained to teach their own sections of the course. The teaching assistants are selected on the basis of talent, personality, and interest in students.

Funding for the course comes from various sources — the School of Engineering, the Office of Undergraduate Affairs, and the Chancellor's Office. The idea that led to the creation of this course was sparked by Dr. Chauncey Starr, former Dean of the School of Engineering and Applied Science at UCLA. Dr. Starr and Professor O'Neill, the present Dean, have supported the course in both deed and spirit from its inception.

Modified versions of this course have been offered since 1973 in the National Science Foundation's Chautauqua Type Short Courses conducted by the American Association for Advancement of Science for college teachers across the country. A public lecture series was offered under the auspices of UCLA Extension to 300 participants from the community which included many professionals from medicine, law, business, education, and industry. Aspects of the course have been presented to various professional societies, executives, and at the annual University of the Young Presidents Organization. A lecture series was also given at the University of Tel Aviv and at the University of Belgrade under the auspices of a Fulbright-Hayes lectureship.

COURSE OBJECTIVES

The primary objectives of the course are:

- To develop a general foundation of problem solving approaches, including some specific techniques.
- To emphasize the thinking processes at all stages of the problem solving activity.
- To expose students to both objective and subjective aspects of problem solving.
- To provide a framework for a better appreciation of the role of tools and concepts that the students may have acquired or will acquire.
- To bring together students from diverse backgrounds so they can observe different attitudes and problem solving styles, and learn from each other.

COURSE CONTENT

Patterns of Problem Solving was designed to provide the foundation for attitudes and skills productive in dealing with complex problems in the context of human values. The most significant feature of the course is its interdisciplinary approach. This is manifested in the diverse background of students in the course and the broad range of subjects covered. The ten chapters of the text Patterns of Problem Solving, Prentice-Hall 1975, which was developed by Professor Rubinstein specifically for the course, reflect this approach:

- Chapter 1: Problem Solving: culture, values and models of problem solving; difficulties, guides and attitudes.
- Chapter 2: Language and Communication: from evolution of writing to computer language, symbolic representation.
- Chapter 3: Computers — Fundamental Concepts: computers, their structure, their use in problem solving, how they work.
- Chapter 4: Probability and the Will to Doubt: information, its relevance, credibility and measurement, entropy.
- Chapter 5: Models and Modeling: purpose and nature of models, models in history, behavioral science, and engineering.
- Chapter 6: Probabilistic Models: samples, distributions, errors of omission and commission, simulation.
- Chapter 7: Decision-making Models: decision criteria, utility theory, game theory, group decisions.

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- Chapter 8: Optimization Models — Selecting the Best Possible: linear and nonlinear programming, dynamic programming.
 - Chapter 9: Dynamic Systems Models: cybernetics, its ubiquity, history, and applications; simulation of dynamic systems.
 - Chapter 10: Values and Models of Behavior: value judgement, social preferences, consensus, assessment of values.

The entire subject matter of the text was not intended to be taught in a ten-week quarter. The subjects taught, and the extent to which they are covered depend on the instructor's prerogative. However, there is a core of subject matter upon which every instructor focuses. This core comprises the major part of the text and course and includes Chapters 1, 2, 4, 5, 7, and parts of 10. The material of Chapters 3, 6, 8, and 9 is dealt with only to the extent that each instructor desires. The text is not the only source of subject material. Some topics covered during the quarter are those which an instructor introduces as a result of individual background.

The emphasis on practical application reflects both classroom and nonclassroom experiences. Instructors often use real world examples in their lectures and assignments, and most instructors require the students to apply the tools they have learned to a personal problem. This becomes the class project. Projects in the past have covered such diverse subjects as selecting a career, buying a car, and finding a place to live. These projects are submitted in written form, and in addition, some are presented orally, shown on film, or illustrated by use of slides. Most of the students enjoy working on their projects and consider their efforts valuable.

STAFF TRAINING

Each June teaching assistants and peer teachers undergo intensive training in preparation for their teaching roles the ensuing Fall. The training program consists of a series of meetings in which basic course content is reviewed, supplementary material is presented, teaching skills are developed, and course policies are discussed. Teaching assistants are videotaped while conducting simulated class lectures. They plan a sample course syllabus and share ideas on course content, lecture styles, and grading systems. Peer teachers review course material by preparing notebooks of lecture outlines, answers to textbook problems, and additional reference material. Peers also practice explaining course concepts in role-playing sessions in the learning laboratory. Perhaps most important, the staff learns to work together and develops a sense of community which continues to grow throughout the academic year. The training program has been extremely successful. Participants in the program feel that it is very worthwhile and that they have acquired knowledge and confidence in preparation for the new academic year.

In addition to the summer training program, the course staff of about thirty people, gets together each quarter at the Rubinstein home to share experiences and suggest innovations for the program. These get-togethers serve as forums for promoting the growth of the sense of community among the staff and students. For example, instructors and peers have planned end-of-quarter class parties, organized Mastermind tournaments, and formed an intramural coed football team. A recent addition is a Patterns of Problem Solving Tee shirt displaying the cover of the textbook. Also, one peer teacher presented the program with a log book for the lab room in which students, peers, instructors, and visitors are encouraged to enter comments, puzzles, and suggestions. This sense of community is displayed by the many times that students and staff plan sessions with food, so they can "eat together while learning together."

THE FIRST DAY OF THE COURSE — ONE EXAMPLE

"Welcome to Patterns of Problem Solving. During this introductory course we will explore many problem solving styles and techniques. But first, here is a problem for you....

"You are lost on the moon, your ship has just crash landed and you and your crewmates have been able to save the following items:

a box of matches, food concentrate, nylon rope, parachute silk, solar powered portable heating unit, two .35 caliber pistols, one case of dehydrated milk, two 100 pound tanks of oxygen, a stellar map, a self-inflating life raft, a magnetic compass, five gallons of water, signal flares, a first aid kit containing injection needles, solar powered FM receiver-transmitter.

"The mother ship is 200 miles away on the lighted surface of the moon. Rank the items according to their potential for helping you survive."¹

Immediately the students, who earlier were divided into small groups, become immersed in a problem. How should we decide? How could we rank the items? How can a group reach consensus? How can we try to overcome the uncertainties in the situation? Will a flare work in the moon's atmosphere? What is more important to us: food or shelter? What is more important: food or water?.....

This "lost on the moon" exercise is then used to illustrate many of the topics which will be covered during the Patterns of

¹This "Lost on the Moon" exercise is from Psychology Today, Nov. 1971.

Problem Solving course. Students realize that they have a problem since there is a difference between where they are (initial state) and the mother ship 200 miles away (the goal state). They are trying to decide how to solve their problem. Thus, they are attempting to determine a specific procedure for reaching their goal state from the initial state. Each group must analyze the alternatives available to it and make some sort of group decision. The students also will want to develop a means for coping with the uncertainties inherent in the problem. They may not know, for example, how long it would take them to walk to the mother ship, but they might be able to estimate probabilities. As they attempt to rank the fifteen salvaged items they would profit from the course discussions on utility theory. Throughout their work on this problem, students will realize that values play an important part in the way we view problems. In such a life-and-death situation, the supreme value of survival will probably overshadow the values of comfort or beauty. Finally, this simulated problem solving situation is just a model of a real situation. Its purpose is to approximate a real problem so students can practice their skills and analyze their own problem solving styles.

THE CONDUCT OF THE COURSE AND THE LEARNING LABORATORY

Patterns of Problem Solving is unique in that along with its diverse academic content, many alternate learning modes are provided. Each section of the course has around forty students, so there is ample opportunity for close interactions among the students, instructor, and peer teachers. The format of class meetings varies; including lectures, group exercises, movies, and problem solving sessions. Assignments may include homework problems, journals, individual problem solving projects, take-home quizzes, and in-class exams.

Outside of class, students are encouraged to go to the course learning laboratory when they need to talk about their homework. The lab room is staffed five hours daily by peer teachers and instructors and provides a meeting ground for students to study and receive help or feedback. Often students come to the lab room during office hours of the peer teacher who is assigned to their class section, but they may ask questions of any staff member. Students can leave messages for peer teachers or instructors in their mailboxes in the lab. Also, answers to homework assignments and additional information are posted on the bulletin board in the lab room. Many students are amazed that the staff is so available and so helpful. Students especially appreciate the fact that undergraduate peer teachers are available to help others master the course material, and some students express interest in becoming peers themselves.

The undergraduate students who become peer teachers have been outstanding students in the course and are invited by their instructors to join the peer teaching program. For these students,

being a peer teacher is more than just a job. From a peer teacher's viewpoint, perhaps the most rewarding aspect of peer teaching is the opportunity to actively contribute to the educational system. Often university students become passive receptacles of facts; peer teaching combats this passivity. Peers focus attention on the educational process and think about alternate methods to teach certain concepts. They become more aware of what occurs in the classroom, and provide needed feedback to the course instructor.

Peer teachers assist in a specific course section in a number of ways. They attend class lectures; read homework, exams, and projects; and assist in running the course. As previously mentioned, peers conduct office hours in the course lab room. In the lab room, students and peers interact on a one-to-one basis. Students realize that the peer cares about them and wants them to understand the concepts. Peer teachers gain a solid understanding of the fundamental academic aspects of the course and also become proficient at explaining these concepts. Peers also gain confidence in dealing with people. Often a peer finds that a student really wants friendly, helpful reassurance as well as clarification of a point from the class lecture. Some peers become very interested in teaching and adopt that as one of their lifetime goals, but all peers have found the problem solving training very beneficial as they embarked on a career or continued their studies.

REWARDING EXPERIENCE

Patterns of Problem Solving has been a rewarding experience for individuals involved in all aspects of the program. Students feel the course is very enlightening. They appreciate the practical course content and the personal attention. Outstanding students often become very interested in the material and continue to take related courses. Twice a year the follow-up seminar course, Applied Patterns of Problem Solving, is offered to a select group of excellent Patterns of Problem Solving students. These students are specially invited by their instructors to take the seminar. Students consider it an honor to be invited to participate in the seminar. In this course, more advanced topics are studied and students conduct in-depth group projects. One group designed a "UCLA GAME" which is used at UCLA's incoming student orientation to introduce the campus and its regulations to newcomers. Another group analyzed the Planning, Programming, and Budgeting System (P.P.B.S.) at a Southern California high school. Other topics have included improving the UCLA fraternity and sorority system and forming a small business. Students sometimes continue these projects by taking independent study courses.

Not only outstanding students find the course appealing. Many students who have not been exposed to problem solving concepts before find them fascinating. One student, for example, worked very hard throughout the quarter attempting to understand concepts that were

alien to him. He was very proud to earn a grade of "C" at the end of the class and thanked the teacher for the only course he'd enjoyed at the university! This student was especially aided by the daily availability of help in the course learning laboratory. Patterns of Problem Solving may be unique in that both instructors and students consider the course to be a valuable learning experience. This fact is at the very heart of the reasons for the phenomenal success of the course.

There are many benefits for course instructors. Instructors often share the same offices. They maintain common office hours in the learning laboratory and meet to discuss their experiences in social get-togethers several times a year. The effects of this constant fraternization are several. The instructors develop close personal friendships. (Two of the instructors even got married!) They exchange information on the course, based on their own area of expertise; share amusing (or frustrating) experiences; develop new problems, examination questions, and class examples; and help each other in some of the more difficult aspects of the course content. They also discuss some of the more philosophical aspects of teaching: the role of the peer teacher; the best ways to make use of student skills; the proper amount of discussion versus lecture; and so on.

An informal tradition exists that some aspects of the course content, emphasis, examples, and so on, are always changing. Part of this results from the interchange of ideas among the instructors; as new ideas are developed and are successful, they are communicated to the other instructors and adopted. But more than this, the instructors fundamentally believe in one of the bases of the course content: one must maintain an open mind, a will to doubt, and flexibility. They believe that, in a dynamic world, it makes little sense to set one's plans in concrete, especially in a course that purports to teach the skills necessary to solve real-world problems. Furthermore, the instructors are taught, and believe, that all classes are different; courses have personalities just as people do and one does not treat all classes alike any more than he would treat all people alike. Oftentimes an instructor will modify his teaching technique or the course content to accommodate a particular class of students.

Instructors maintain an honest respect for their students. In a sense, this is a necessity, because in a course that covers subjects from psychology to linguistics to physics to engineering, there may be students who know more about some given subject than the instructor.

Finally, and perhaps most important, if there exists a philosophy common to the instructors it is that the course, and teaching it, ought to be fun. While instructors are not hired because of their senses of humor, it never seems to fail that the type of people who enjoy the course enough to pursue it further and to eventually end up teaching it are the kind of people who enjoy life and are

happy. They neither take themselves, nor the world, too seriously and they know that students do not learn much in a course which they dread attending.

CONCLUSION

Patterns of Problem Solving has had a record of success virtually unheard of in academia. The reasons for this success are the course content itself, which is flexible and designed to instill in the student the skills and attitudes productive for dealing with complex problems; the preparation and training of the staff involved in teaching the course; the varied format of the actual teaching; the availability and helpfulness of the staff, including the existence of a "learning laboratory," where students can receive individual attention directed towards their particular needs; and the enthusiasm, and concomitant effectiveness, of the instructors.

We feel that as the teaching of problem solving becomes more widespread, it is fundamental that the organizers of such courses examine not only the content of the course but the atmosphere in which it is conducted.

THE AUTHORS

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Moshe Rubinstein created the campus-wide course "Patterns of Problem Solving." He is author of four textbooks and more than sixty publications in the areas of problem solving, decision theory, dynamic response, and structural systems. He has received many awards for his teaching excellence. He has lectured widely throughout the country and abroad. Moshe Rubinstein is listed in Who's Who in America and is a graduate of UCLA, having received his B.S. in 1954, M.S. in 1957, and Ph.D. in 1961.

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For the past five years Robin Keller has been associated with the Problem Solving Program as student, peer teacher, and instructor. She received a Bachelor's Degree in Mathematics at UCLA and a Master's Degree in Business Administration from the UCLA Graduate School of Management. Robin is pursuing a Doctorate in Management Science at UCLA with a special interest in problem solving. She is affiliated with Beta Gamma Sigma, the national business honorary society.

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