ON TEACHING PROBLEM SOLVING
Part II: The Challenges

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A SURVEY OF HOW various individuals or institutions teach problem solving skills has been reviewed [83]. What are the challenges or difficulties encountered in trying to improve a student's skills in solving problems and what are some ideas for overcoming these challenges?

The overall challenge in general is well described by Hilko [60]†, a student from University of Waterloo, and by Hupert [61], a professor from De Paul University. Hilko says that using problem solving to test or give practice in knowledge gained does not necessarily give training in how to think. The need is to provide formal descriptions of problem solving, the strategy and the elements therein, so as to make explicit what many have learned consciously or subconsciously and emphasize universality of approach. Hupert comments that there are two sides to every academic discipline: (a) knowledge and (b) skill (including problem solving). An academic course which does not handle both sides is a half-baked enterprise and does not fulfill its objective.

The specific challenges according to the respondees are a mixture of four:

- **difficulties with students' backgrounds, abilities and attitudes, (the prerequisites),**
- **difficulties with the subject,**
- **difficulties students have with the subject of problem solving,**
- **difficulties instructors have in teaching it.**

Each is discussed in turn.

†References continue from those given in Part I [83].

BACKGROUNDS, ABILITIES AND ATTITUDES

IN PART I, I tried to limit this survey to those efforts being made to improve problem solving and not those to improve the host of prerequisite skills. Yet, here we must face any difficulties students have with the prerequisites. The respondees said that the students

- **are weak in the basic technical knowledge(scientific or medical)**
- **lack elementary skills in logic (do not draw appropriate conclusions from the information they have, and cannot correctly reason deductively,**
- **are weak in communication skills,**
- **have acquired bad habits for solving problems, or do not recognize that they have any problem solving skill. (This was expressed as 'we expect to acquire problem solving techniques somewhere, but they don't, students jump in and follow a gut feeling instead of taking a more systematic approach, students do not examine alternative strategies or cannot think up alternatives students are not aware of what they are doing when they solve problems),**
- **lack the motivation. (This was expressed as 'the students won't grasp opportunities to improve themselves and they want to collect type problems instead of applying basic knowledge to solve new situation problems on their own),**
- **fail to recognize that problem solving in itself is a legitimate educational goal,**
- **do not emulate good problem solving.**

Some difficulties are training and convincing faculty that problem solving is in itself a legitimate educational goal. As a personal aside, just about everyone thinks that they "teach problem solving"; everyone is an expert. If one tries to do something about teaching problem solving skills, then we must be prepared for a wide variety of comments. Some ask "Who is he that he thinks he knows how to teach problem solving?" Some

say, "It can't be taught." Some say "Everyone's doing it so why make a big deal out of it?" Another difficulty is in identifying or specifying an algorithmic approach for each strategy that identifies the discrete skills and behaviors to be performed. Respondees said it was difficult to identify the necessary skills and to test for them. And last they found difficulty in convincing students that the extra effort required to learn a procedure or new terminology (such as a meta language) is worth the effort.

PROBLEM SOLVING STRATEGY

THERE ARE A HOST of different listings of the steps that make up the overall strategy for solving problems. Some of these are listed in Table 1. Some respondees identified the steps or activities that gave the most difficulty to be:

- subsystem identification and relationships among the subsystems,
- relating subsystems to theory and the question asked,
- translating physical problem into a mathematical description,
- simplifying complex problem or making good assumptions,
- being creative,
- asking general questions first; asking specific questions later,
- creating a hypothesis,
- how to ask the right questions,
- anything to do with analysis.

more specifically as difficulty in posing problems so that students develop understanding of general principles and general problem solving strategy rather than memorizing solutions to specific "type" problems; posing problems appropriate to students' skills and sufficiently modest to enable the student to have adequate success with them, and finding the time required to prepare good problems,

- to find the time to prepare the lecture notes, the problems or other materials; It is interesting that most have developed their own set of notes or problems,
- to get students to see the underlying problem solving process

CONCERNING THE METHOD

Teaching problem solving offers challenges in the area of method.

The challenges cited are:

One challenge cited was keeping the course interesting and moving especially after the students realize that they are not going to get answers to all their real life problems.

Challenges as discussion leader include:

- pacing the discussion so that all participate,
- structuring the discussion so that all see a logical structure,
- not overstructuring the problem solving learning situation,
- knowing when to intervene and when to let the students go out on a limb,
- controlling the sessions, keep the group on track

One challenge cited was keeping the course interesting and moving especially after the students realize that they are not going to get answers to all their real life problems. Another challenge involved in the methods of teaching problem solving is to give the students sufficient practice that they have confidence in applying a problem solving strategy.

Most of the challenges listed by the respondees concerned how to teach it. One needs to overcome the reluctance of instructors to give such an open-ended course, to try to describe how they solve problems, to try to solve problems they have not seen before and when they might fail. One should get the experience into the curriculum at the right time, or to match the education program with problem solving strategies used in actual practice.

Some of the difficulties given by the respondees in regard to content preparation are listed below.

- to locate a good text that is acceptable by the students, or to locate good resource people,
- to get good problems to work on. This was described

and to prevent students from bringing in personal problems for the other students to solve,

- as an instructor, avoiding philosophizing and lecturing, but to set the ground rules,
- not squashing creativity,
- as an instructor, refraining from becoming part of the problem or of the solution,
- knowing when to stop because the problem is giving diminishing returns for learning about problem solving; especially when they want to continue brainstorming,
- getting effective groups that work together and where everyone participates.

Another challenge involved in the methods of teaching problem solving is to give the students sufficient practice that they have confidence in applying a problem solving strategy and to get

TABLE 1: SOME STRATEGIES FOR SOLVING PROBLEMS

D'ZURILLA & GOLDFRIED[2]	BLOOM & BRODER[74]	WALLAS (1926) [see DAVIS[1] p.16]	KINGSLEY & GARRY (1957) [see DAVIS[1] p. 16]	DOUGLAS[21]
1. General orientation (recognize problem exists & be positive in approach)	1. Understand nature of problem	1. Preparation	1. Difficulty felt	1. Idea generation or indentify problem
2. Problem definition & formulation	2. Understand ideas contained in problem	2. Incubation	2. Problem clarified & defined	2. Initial screen
3. Generation of alternatives	3. Procedures used	3. Inspiration	3. Search for clues is made	3. Complete the problem statement & define critical steps
				4. Translate
				5. Sketch a diagram
				6. Sketch to guess better answer
			4. Various suggestions appear & are tried out	7. List assumptions & try simplest analysis
4. Decision making			5A. Suggested solution is accepted	8. Estimate solution
5. Verification	4. Attitudes toward the solution	4. Verification	6. The solution is tested	9. Evaluate & explore implications

POLYA[5]	WOODS et al[81]	RICHARDS[14]	SMALL[15]	AUBEL[82]	EASTBURN[51]	FULLER[27]
1. Define	1. Define	1. Identify objectives	1. Observe/ gather information	1. Set up problem	1. Fact finding	1. Choose point of view
					2. Problem finding	2. Compose problem
	2. Think about it	2. Identify important variables	2. Formulate hypothesis	2. Analysis: physics	3. Idea finding	3. Assess composed problem
2. Plan	3. Plan	3. Use dimensional analysis	3. Design test			4. Choose most valuable problem to try to solve
		4. Identify apparatus to be used		3. Analysis: math		5. Sort out information
		5. Plan tests				6. Propose potential solutions
		6. Plan data recording activities				
3. Carry out the plan	4. Carry out the plan		4. Interpret data		4. Solution finding	
		Interpret control curves	5. Is hypothesis confirmed?			
4. Look back	5. Look back	decide how results should be reported, what results mean ask "is test finished?" "am I finished?"			5. Acceptance-finding	7. Evaluate 8. Recommend action

STAGER[34]	MAGAZINE[50]
1. Recognize problem	1. Problem formulation
2. State basic objective	2. Data collection
3. Gather information	3. Abstraction
4. State constraints, facts assumptions	4. Quantitative model
5. Generate possible solutions	5. Deduction
	6. Analysis
6. Evaluate and make decision	7. Interpretation
7. Analysis, synthesis & evaluation of solution	8. Data collection & verification
8. Report results & recommend action	

the students to translate a problem solving skill from one problem to another, or from a problem solving course to their "other" courses, or from academic problems to their personal problems. There is also a challenge to provide consistent information to each group (when having many groups doing the same problem).

Two challenges in evaluation are: measuring and evaluating student performance; and evaluating what we have done.

IDEAS FOR THE FUTURE

HERE ARE SOME ideas for discussion based on the responses summarized in this report.

Small group tutorial—The advantages of the small group tutorial as a means of teaching problem solving seem to have been emphasized. If this is the way for us to proceed then for the large introductory classes, this required a large faculty commitment and good tutors. Is there any other way we can achieve these advantages? or can we afford to take this approach or perhaps; can we afford not to?

Everyday homework base—Many seem to have imaginative courses for solving the large open-ended problems. Have we provided sufficient basis for good problem solving habits for those students entering such courses? Are the students learning anything about problem solving from the usual everyday assignments? What should or could be done to provide students with good habits for solving the everyday assignments?

Overcoming learning skills deficiencies—Many students are not proficient at self learning or at collecting and evaluating information for themselves. They have difficulty identifying the key ideas of knowledge nor can they see how these ideas are interrelated. These are necessary prerequisites to being good problem solvers. When and how can these be taught?

When—Those who have a special problem solving emphasis in the more senior years get student response: "we wish that we had this sooner." When should different elements of problem solving be taught? What should the relationship be between the university and college and the high school programs?

Translation of skills—Those who have courses primarily on problem solving find that the students have difficulty translating what they have learned to other courses and situations. How can we overcome this problem?

Communication—The literature on problem solving and creativity is extensive, and it is difficult to discover resources that are pertinent to individual needs. Some references have been listed in the bibliography. Some additional resources that might be useful include:

- **In the area of engineering design:**
  Jones [62], Dixon [63], Krick [64], Asimow [65] and Buhl [66].
- **In the area of mathematics:**
  Jenson and Jeffreys [67], Chapter 1 and especially p. 21, and Himmelblau and Bischoff [68], Chapter 1.
- **In the area of business:**
  Achoff [69]. Two very interesting little example books are the UNESCO publications, Servais and Varga [70] and Lewis [71].
- **In the area of puzzles:**
  Fixx [72] and Sobol [73].
- **In the area of thinking and problem solving:**
  Bloom and Broder [74], Buzan [75], Survival Problem [76].

Despite the apparent differences in discipline and in approach there are great similarities in the types of problem and in the method of solving it. A challenging question is how can those interested in teaching problem solving maintain contact and share ideas?

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SUMMARY

The challenges to presenting a course in problem solving cited by the respondees were summarized as difficulties with the student's background, with the subject, with the student's understanding of the subject and with teaching it.

Some suggested follow up questions are posed and some answers given.

As a postscript, at McMaster we are complementing this survey with a four year experiment to try to discover specific approaches that we should take to improve our student's ability to solve problems. This work is described elsewhere [79, 80, 81].

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DISTINGUISHED PROFESSOR TITLE TO LARSON

AMES, IOWA—Maurice A. Larson, professor of chemical engineering at Iowa State University has been awarded the Anson Marston Distinguished Professorship in Engineering.

Larson, born in Mirrouri Valley, was graduated from high school at Ayrshire in 1944. He received his B.S. (1951) and Ph.D. (1958) degrees from Iowa State and was a chemical engineer with Dow Corning in Midland, Michigan, 1951-1954. In 1954 he became a teaching assistant at ISU, was named an instructor a year later and has been on the faculty since then. In 1970 he received the Western Electric Fund Award for excellence in teaching. In 1967 he had received ISU's Webber Teaching Award for inspired teaching in chemical engineering, and in 1972, received the Faculty Citation. In 1971-72 Larson was a visiting professor at University College, London, England. He was an AID-NSF science education consultant in India in 1968.