Patterns of Problem-Solving

A Final Report of Work Undertaken with the Support of the Lilly Endowment

by

Steven J. Bartlett

Visiting Scholar in Philosophy and Psychology, Willamette University
and
Senior Research Professor, Oregon State University

Website: http://www.willamette.edu/~sbartlet

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PATTERNS OF PROBLEM SOLVING:

A Final Report of Work

Undertaken with the Support

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Administered at Saint Louis University
by Project C. O. V. E.

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Principal Investigator: Dr. Steven Bartlett
Department of Philosophy
Saint Louis University

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Problem Solving Program, UCLA, for his willingness to share efforts made over several years to establish what is probably the largest and is certainly the finest undergraduate program in problem-solving currently available in this country. Grateful acknowledgement is made of several informal communication formats prepared by the Creative Problem Solving Program, from which I have borrowed unabashedly here and there.

PART I

Problem-Solving: A New Area of Curriculum Development

A. The Context for an Alternative Approach to Learning.

Throughout its historical development, the university has embodied

acceptance of a general paradigm of scholarly learning. This paradigm

has been expressed in the practice of the university's approach to education,

though not always in its theory. In its actual day-to-day orientation toward

learning, the university has placed a nearly exclusive emphasis upon training

students to know that, seeking to pass on to each new generation a content-

based heritage. From its adherence to this paradigm, the university has

viewed itself as existing primarily to transmit the cultural heritage and to

impart information.

The resulting subject-centered curriculum has been dominated by the

storage concept of learning : The purpose of education is preparation for

future living; the student stores information for subsequent use. The storage

concept of learning suggests that there are certain basic essentials any

educated person must master to be educated. Since these essentials are

defined in terms of projected needs and interests of students in their future

lives as professional adults, it cannot be assumed that the student will have

attitudes appropriate to what is learned now. Hence the need for authority,

and a past-oriented concern for a cultural heritage to be transmitted.

The content-based paradigm and the storage concept of learning

have led almost axiomatically to a comparatively rigid set of beliefs:

- One cannot expect students to have the interests
  which arise only in later living. Hence, education,
  to be effective in terms of mastery of content,
  requires the presence of punishment/reward
  mechanisms extrinsic to the learning process.

- Intelligence is a fixed quantity, hence an individual
  has only so much potential for intellectual growth
  and is capable of storing only so much information.

- For lack of either of the above, motivation or
  intelligence, some students will be poor learners,
  and for these individuals, education must expect
  a lower level of success/achievement.

The first of these beliefs is inclined to be self-fulfilling. Since the

prescriptions of the content-based curriculum are based on projected needs

and interests of students in their future lives, it cannot be expected that

most students will experience needs and interests which arise in the context

of real-life problems they have yet to face. It is expedient to replace the

genuine values of learning, which students are not yet in a position to appreciate,

with artificial substitutes in the form of grades, degrees, and other authority-

based expressions of approval. The needs and interests these substitute

values encourage have led education down a path that becomes increasingly

less rosy, as the evidence of soaring grades and reduced mastery of content

indicates.

The second belief is simply an expression of a mistaken myth, as

recent studies of intelligence have indicated. Students can and do improve

intellectual skills which have been used to define 'intelligence', while much is being learned about the design of formats for learning which are especially helpful in encouraging development of cognitive skills.

The standards set by these two beliefs have necessarily been tolerant, since the failure of some students, hopefully a relatively small number, to perform satisfactorily was expected.

But expectations along this line have been unrealistic, in fact, excessively optimistic. The content-based curriculum is currently losing approximately 35 - 50% of its students before entrance to college.* Thousands more find themselves occupying space in universities because of external pressures, frequently in the form of a need for professional certification to be eligible for employment.

But now also this belief in the relevance of university-level study to subsequent employment is crumbling. It is now projected that today's high school and college graduates will have to retrain or be re-educated between four to six times during a life of normal expectancy.** Already, we see that 25% of the bachelor's degree holders in the work force have jobs that did not exist five years ago.

In short, the content-based paradigm is undergoing accelerating stress: (i) Its storage concept of learning requires motivational encourage-

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* Otto Hollaway, Problem Solving: Toward a More Humanizing Curriculum (Philadelphia: Franklin Publishing Co. 1975), p. 12. Hollaway claims that this drop-out rate, if it continues, will lead to 25% unemployment of the adult population by the 1980's.

** Ibid., p. 13.

ment from artificial, substitute goals, which are systematically mistaken as the proper objectives of "good" students, to the detriment of traditional values. (ii) The myth of fixed intelligence is rapidly giving way, thanks to recent empirical studies. (iii) The content-based paradigm is both able to attract fewer students, and is progressively less effective in transmitting information which in fact will prove useful to students in a world of rapid change.

B. A Problem-Solving Approach to Learning.

A problem-solving approach to learning is one of a number of approaches which together can respond to this challenge. The philosophical roots of the problem-solving approach are found among those of the western intellectual tradition, in the Greek belief in the convergence of rationality and conviction, through a process of engaging the student in reflective analysis. If this is yet another footnote to Plato, the main text on problem-solving as a tool of education was probably a composite product of a group of American scholars -- among them, Charles Sanders Peirce, John Dewey, William James, George Herbert, Robert Hutchins. One view, the one relevant here, that emerged from this tradition spanning many centuries, through dialectic to pragmatism, advocates a participatory function of education: Education can be more than a preparation through storage of information for future and now often unforeseen applications. It can involve the active working together of instructor and students in the context of selected problems, problems which

encourage in the problem-solver an involvement both with the values represented by the problem, and with the tools -- information and techniques -- by means of which the problem can be solved.

Interestingly enough, it turns out that students find a problem-solving approach to learning exciting and intrinsically satisfying. There is some evidence now (see below) that problem-solving approaches to learning develop and improve dramatically the general cognitive skills of many students. Furthermore, in a world experiencing an unprecedented explosion of information, the content-based paradigm of education stands in need of reform to provide students with the tools they need to cope successfully with change. In this context, a dialectic, pragmatic, participant-oriented, problem-solving approach can provide a useful means to deal intelligently with rapidly evolving information.

Where the success of the storage concept of learning is often based on the sometimes seductive, sometimes authoritarian ability to use extrinsic motivation, a problem-solving approach to learning (a) enables students to discover personal meaning in problem situations which they must resolve, (b) provides students with an awareness of immediate as well as long-term benefits of their work, and (c) assists students in improving sifnificantly their intellectual skills. These are intrinsic satisfactions which motivate students to direct their energies in improving themselves through education, rather than primarily in improving their grade point averages and purchasing degrees.

It is now widely recognized that techniques and skills in problem-solving are fundamental to many disciplines. Such distinguished scholars as Alfred Tarski and George Polya have for some time advised that problem-solving techniques and skills have a basic status in nearly all academically represented disciplines. But only recently has their advice come to have concrete, empirical support.

The ALL (Accelerated Learning of Logic) Project, under the direction of Professor Layman E. Allen at the Yale Law School, obtained these results: It is possible to achieve a measurably high success in training students in the use of logical techniques of problem-solving, and accomplish this in a relatively short time (e.g., 29 days). Even within such short periods of time, students showed a significant improvement in general reasoning abilities as measured on a standard IQ test (California Test of Mental Maturity).

Another study, under the direction of Professors Albert Upton and Richard Samson, at Whittier College in California, reached similar results (also using the CTMM as an indicator of change in level of reasoning).

The present study undertaken with the support of the Lilly Endowment obtained significant changes in levels of reasoning of students (also using the CTMM). (See below for a description of results.)

The evidence points toward this conclusion: That what we commonly refer to as "intelligence", and measure by means of, e.g., IQ tests, is the expression of general problem-solving skills which themselves can be investigated explicitly, and can successfully be taught. Where once we thought

of education as a response to a pre-existing fixed quantity of intelligence, we have begun to see that problem-solving intelligence is, to a significant degree, a function of education.

C. The General Objectives of Problem-Solving Instruction at the University Level.

Colleges and universities now offering courses or entire programs in problem-solving appear to be in fair general agreement about the nature of problem-solving instruction, its role within existing programs of study, and student objectives.

It is generally accepted, even at this early stage in the development of academic problem-solving, that general problem-solving is not a discipline as such, but is rather a focus for interdisciplinary cooperation. In this sense, it is commonly agreed that the study of problem-solving is not an effort to establish a new breed of department, or otherwise accept a territorial view toward problem-solving.

To varying degrees, existing programs and courses in problem-solving seek to develop

- a sophisticated awareness of the levels of complexity of problems, and of the inadequacy of simplistic approaches and limited perspectives;

- an awareness of the boundaries of one's professional perspectives, skills, and set of familiar concepts;

- an ability to interrelate one's limited professional competencies with those of others to approach a holistic attitude in problem-solving;

- an experience of the importance of other disciplines to one's professional responsibilities;

- an open-ended set of skills basic to, and a commitment to take responsibility for, one's continued educational development;

- an awareness of the need for scholarly procedures to accomodate the divergent values, biases, forms of self-interest, presuppositions, and constraints normally built into the structure of complex problems;

- a consciousness of some of the dimensions of creative problem-solving and of blocks to creativity in the formation and resolution of problems;

- a commitment to the values of, and to the search for, holistic perspectives on human problems, perspectives that effectively integrate insights from the humanities, sciences, and the professions.

D. The Growth of University-level Interest in Problem-Solving.

At the time of this report (April, 1977), approximately thirty major universities have been identified which have initiated courses or programs devoted to general problem-solving. There appears to be considerable interest on the part of other colleges and universities to begin similar programs. The National Science Foundation and the American Association for the Advancement of Science have together sponsored a series of short-courses for college science faculty across the country, relating to general problem-solving and to development of student reasoning. Major corporations are rapidly becoming interested in training for their employees in problem-solving, and in problem-solving applications. Finally, a number of major foundations and other institutional funding sources have become

interested in supporting university curriculum developments involving

problem-solving.

From these signs, it is clear that the design and implementation of

courses and programs in general problem-solving at the university level

constitute a new and growing concern. However, institutions seeking to

develop a problem-solving curriculum component are usually unable to

profit from the experiences of colleges and universities which have already

developed courses and programs, for lack of dissemination of information.

Since sound programs do not often come into being by chance alone, there is

a real need for an integrated national study of problem-solving in the United

States. (See below, Conclusion, B.)

PART II

Planning, Design, and Implementation of a

Campuswide Course in General Problem-Solving

A. Background.

Two experiences involved me in a problem-solving approach to

education. The first occurred over a period of several years, while

teaching at the University of Florida and the University of Hartford, where

I became interested in developing new and more effective formats for

learning formal logical problem-solving skills. Out of this work, I published

a non-simulation learning game approach to problem-solving techniques in

mathematical logic. The participatory involvement that such a creative

learning game approach provides students, as a supplement to normal

lectures and text, appears to accomplish two things: Students very quickly

acquire a personal interest in the subject matter, and develop an easy sense

of technical competence. Frequently, I had come to see that both personal

meaning and a technical ease and familiarity were not acquired in a straight

lecture-type of course. It should be remarked in this connection that there

are now indications that knowledge gained in a lecture situation is retained

for a comparatively short time, whereas knowledge developed through

participatory problem-solving is retained much longer. *

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* See, for example, Fund for the Improvement of Postsecondary

The second experience which intensified my interest in a problem-solving approach to learning took place over the two academic years, 1975-76 and 1976-77. I participated in two prgrams for university science faculty, held at the University of Missouri, Kansas City, sponsored by the AAAS with the support of NSF. The first program, which involved two meetings in October, 1975, and February, 1976, provided an opportunity for selected faculty to study general problem-solving as a field of importance in higher education. At the February meeting, I presented the results of research undertaken ("A Metatheoretical Basis for Interpretations of Problem-Solving Behavior", forthcoming in <u>Methodology and Science: Interdisciplinary Journal for the Empirical Study of the Foundations of Science and their Methodology</u>). The second program also involved a pair of meetings, in November, 1976, and April, 1977. The focus of these meetings was research by Piaget and others which is now being applied at a small number of institutions, in the form of a developmental approach to the learning of reasoning skills by university students. At the April meeting, I presented the results

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Education, Program Information and Application Procedures, Department of Health, Education and Welfare, Document PMB No. 85-R-0287, p. 11, 1975, and University of Nebraska - Lincoln, ADAPT (Accent on Developing Abstract Processes of Thought) Program, monograph report, 1976, which contains many references to other studies.

of research undertaken, concerning relationships betweeen Piagetian proportional reasoning, on the one hand, and general problem-solving skills, language, non-language, and total IQ scores, on the other.

B. Spring and Summer, 1976.

I received funding through Project C. O. V. E. to initiate research during the Spring and Summer of 1976, in the field of general problem-solving. It was expected that this work would lead to the design of a course in general problem-solving, open to students of all majors, and to be offered for the first time at Saint Louis University in the Fall of 1976. This work focussed on the following areas:

a. Developmental theory of learning, with special emphasis on acquisition of cognitive skills involving ascending levels of abstraction: particular attention to practical teaching methods, concrete models, and principles of ordering skills to be mastered as a function of levels of abstraction;

b. Applications of algorithms to problem-solving skill development;

c. Use of mnemonic devices in the development of problem-solving skills;

d. The influence of affective distractors on learning and retention of problem-solving skills;

e. Developmental theory of values formation and its relation to cognitive skills formation;

f. Problem-solving characterizations of human intelligence, and recent work relating to the training of intelligence;

g. Testing and measuring problem-solving abilities;

h. Identification of problem-solving skills needed by students in representative disciplines (i) according to students in each discipline, (ii) according to each major department, and (iii) according to professionals in each field who are involved in determining the suitability of candidates for career opportunities;

i. Means for measuring the skills actually acquired as a result of a course in problem-solving: the design of pre- and post-tests in general problem-solving;

j. Ways to detect student interest in the course offered, via evaluative questionnaires;

k. Ways to detect the degree to which the course has been useful to students, either through a follow-up report by selected students, or through a report by selected departments of the academic success of students who have taken the problem-solving course;

l. Faculty and students were made aware of the course offering, beginning in the Fall, 1976: Letters were sent to all department chairpersons, all academic advisors in all major departments, the Office of Academic Advising; descriptive materials relating to the course were circulated to all faculty of the Department of Philosophy; printed course announcements were posted; the campus newspaper printed an article about the course; planning work was done on a committee with the Dean of the College of Arts and Sciences to formulate a proposal for a new curriculum component in which the proposed course would serve as a core course (see Conclusion, C);

m. Correspondence was initiated with twenty-seven institutions offering courses or programs in problem-solving;

n. Orders were placed for a variety of learning materials, and an initial inventory prepared and circulated to faculty.

C. Fall 1976 and Spring 1977.

The resulting course, Patterns of Problem Solving, was offered for

two semesters. A description of the objectives of the course, content, and

its evaluation is given in Part III, below.

Orders for needed supplies, audio-visual materials, and a small collection of reference works in the field of problem-solving, continue to be processed through Project C. O. V. E. to meet the current and projected needs of students in the course.

Research on general problem-solving was continued, leading to the writing and publication of several papers, copies of which are on file with Project C. O. V. E.

Early in the Spring, the Department of Philosophy met and approved the course as a regular part of the Department's offerings. The course has been approved by the University Curriculum Committee, and is scheduled to be offered on a continuing basis, the next class beginning in the Fall of 1977. The Department of Philosophy has agreed to provide a part-time graduate assistant for the course, and hence the costs for the continuation of the course have been assumed by Saint Louis University, after grant support from the Lilly Endowment terminates.

PART III

The Objectives, Content, and Effectiveness

of the Patterns of Problem Solving Course

A. Objectives.

The Patterns of Problem Solving course was designed to address

the integrative rather than the specializing skills and attitudes needed for the

creative solution of complex problems: The adjective 'creative' is intended

to restrict the scope of inquiry in a flexible way to problems not solvable

by known algorithms -- to problems, that is to say, which require some

invention, discovery, or design with respect either to the formulation of the

problem or the formulation of a solution.

The course seeks to meet, in an open manner, without the normal

self-imposed constraints of the specialized disciplines, the challenge which

most professionals and professional scholars face repeatedly, a challenge

which the nature of problem-solving poses, to which attention can profitably

be paid.

The Patterns of Problem Solving course ideally would contribute to

      a recognition of a challenge
      a commitment to a seach
      a focus for faculty collaboration and development
      an evolutionary model for educational processes
      a synthetic research effort

A recognition of a challenge

Rapid social and technological change present university faculties

with a challenge having three related facets:

- Much of the professional's highly specialized learning is subject to increasingly rapid obsolescence.

- Professionals are facing more complex responsibilities requiring a broader range of knowledge and skills than has traditionally been recognized.

- Rapid changes in social and technological problems increasingly demand effective integration of insights from the separate disciplines.

A commitment to a search

Faculty, deans, and administrators at universities that have recently decided to institute courses in problem-solving have committed themselves to search for ways in which their schools can augment the abilities of their institutions to respond to this challenge: It has been felt that courses in problem-solving may in some small but lasting way facilitate and enhance the faculty collaboration which the challenge requires, but which traditional compartmentalization of values and knowledge in discrete departments has tended to inhibit.

A focus for faculty collaboration

Collaboration requires a focus that interrelates established disciplines. The chosen focus of the Patterns of Problem Solving course is the development and commitment to systematic and holistic approaches to problem-solving characterized by:

- complexity
- the need for creative solutions
- rapid evolution in both the complexity of problems and the sophistication of models and approaches to these problems
- divergent values which provide both the context for the

recognition of a problem as a problem, and for our abilities
to perceive possible solutions
- time pressures for decisions.

Such approaches must effectively interrelate the three different domains

of reality, possibility, and values, and they must effectively integrate

the knowledge, skills, and perspectives from the sciences, the humanities,

and the professions.

An evolutionary model for educational processes

Both as a challenging vehicle for faculty collaboration and as an end

in itself, Patterns of Problem Solving seeks to contribute to a continuously

evolving educational program centered on the chosen focus, and offered as an

augmentation of pre-professional undergraduate learning. Three types of

courses in problem-solving have been envisioned at universities across the

country; these give some idea of the embracing character of problem-solving:

- integrative, introductory, or comprehensive courses, a heading
  under which the Patterns of Problem Solving course belongs;

- courses exploring specific aspects of problem-solving in
  depth, and intended as enduring elements in a group of
  complementary courses;

- ad hoc selections of courses to assure revolving participation
  by a variety of faculty members and to permit continuous
  exploration.

Together, such courses attempt to bring to education a conception of learning

as a dynamic response to a changing environment of human needs.

A synthetic research effort

Faculty participants in most programs in problem-solving are

self-selected, reflecting their interest in the integrative aspects of

undergraduate education and their concern to relate their specialized

disciplines to other disciplines. The aim of the Patterns of Problem Solving course, then, is to contribute to an organized examination of the relevance of the various disciplines and of the applications of their respective methods of scholarship to complex problems. Three complementary avenues for collaborative study are:

(i)   Systematic exploration of creative problem-solving through an investigation of blocks to creativity which occur in the recognition and formulation of problems and in the design or achievement of solutions.

(ii)   Comparative analysis of different disciplinary and professional approaches to problem-solving, including attention to:

- interrelated concepts
- development of integrative frameworks
- development of new hypotheses
- assessment of the adequacy and the validity of existing frameworks and theory
- design of new models and experiments
- comparison of learning/teaching formats

(iii) Collaborative examination of the applicability, and ways to extend the range of applicability, of methods of scholarship to complex problems that transcend the competencies of individual disciplines, and often transcend the current aggregation of scientific knowledge.

In general, the intention behind Patterns of Problem Solving, and behind a problem-solving approach to learning itself, is to stretch disciplines, to focus scholarly inquiry on the interface between disciplines, and to catalyze an interdisciplinary search for holistic approaches to complex problems, combining scientific, humanistic, and professional insights. In essence, Patterns of Problem Solving, and the values it represents, is directed toward the encouragement and support of efforts to promote the integrative, as contrasted with the specializing functions of the university. The view underlying this approach to learning is one which sees in the university

the expression of a community of scholars.

These comprise an unmistakably idealized vision of the problem-solving orientation toward learning. To attempt to realize a few of these purposes, the specific objectives of the course were defined as a function of student responses to questionnaires. The objectives of the course were associated with the following aspects of general problem-solving:

- problem identification and representation
- multi-perspective approaches to problems and solutions
- identification of appropriate, simple perspectives
- abstract thinking
- applications within the student's own discipline
- freedom from constraints imposed by the problem-solver's own perception of problems
- identification of patterns of thought in the problem-solving process
- memory skills
- ability to see relationships and organize ideas
- logical reasoning: practical applications, detecting weaknesses in positions
- decision-making and representation of values
- group problem-solving and effective communication
- improved verbal comprehension abilities
- test-taking skills
- computer applications
- defining personal and group priorities
- making the best use of time
- clarifying the philosophical basis of problem-solving
- understanding problem-solving as an interdisciplinary bridge
- improving employment potential
- use of relaxation techniques to cope with difficult, stressful situations

B. Content.

A considerable amount of research and reflection was needed to transform such a large order into manageable terms. It was decided that most if not all of the above objectives could be achieved in some measure, to the extent that a

one-semester course makes this possible, by concentrating on a comparatively small number of key concerns:

(i) "De-mythologizing problem-solving": By attacking such myths as "good problem-solvers solve problems very rapidly, using only their heads", students are guided to use heuristic devices to formulate problems clearly, represent them simply, and achieve a degree of flexibility in discovering alternative routes to the solution of the same problem.

(ii) In this, attention is given to an analysis of protocol reports (descriptions of one's own cognitive processes in approaching and solving a given problem) elicited from the students. An attempt is made continuously to shift importance away from the simple fact of attaining a solution, to an awareness and understanding of the problem-solving process.

(iii) Emphasis is placed upon problems which cannot be solved by known algorithms (e.g., ready-made formulas). In this, the course seeks to underscore general problem-solving strategies, a consciousness of the values-dimension of all problem-solving, and an awareness of productive attitudes in coping effectively with uncertainty.

(iv) The view of problem-solving dominating the course is holistic: Problem-solving is treated as an essentially human phenomenon, understood in the context of human needs, interests, and valuations. Students are encouraged to view problem-solving not as a collection of techniques, but as a point of intersection of such important variables as ability to cope with stress, sensitivity to alternatives, consciousness of constraints frequently imposed by human perceptions, ability to make effective use of time, aware-

ness of the short- and long-term benefits of problem-solving commitments, repertoire of problem-solving techniques, memory skills, and, at a fundamental level, mental and physical health. In other words, problem-solving is represented in a broad context of human concerns, a context which is defined by multiple dimensions in which mere technical competence is often impotent. The demands made by contemporary problems, in terms of orders of complexity, time pressures for decisions, and a need for original design, -- these demands cannot be met by the more traditional one-dimensional conception of problem-solving as technique.

In this general framework, students are introduced to techniques of critical reasoning, the use of formal representations in modeling actual problem-situations, fundamental concepts of computers, probability, information, and measures of relevance. Decision models, assessment of values, and models and modeling in the humanities, behavioral, and physical sciences are studied.

C. Effectiveness.

A number of indicators can be used to determine the effectiveness of the course.

(a) The most important of these is the degree to which students who take the course profit from the experience in terms of development and improvement of problem-solving competence. This is certainly the primary "performance" or "behavioral objective" of the course. To measure change

in level of problem-solving ability over a semester's work in the course, each student is asked to take a pre- and post-test designed to measure distinct problem-solving skills. (A copy of each test is on file with Project C. O. V. E.)

Results concerning the Fall semester class are given in the attached supplements. The mean improvement of students in the class was 84. 5% over their pre-test scores. Apparently, the "entry skills" of students are improved significantly by the course.

(b) A second and central objective of the course is to provide each student with a repertoire of productive problem-solving skills and attitudes which will be of utility to the student personally, academically, and professionally.

The results of student course evaluation questionnaires (see supplement) indicate that students rate the course highly in terms of the course's response to problem-solving skills which they identified as important to them on a personal level.

Although students have indicated they believe the course is of considerable value to them in other courses and major programs of study, insufficient time has passed for a follow-up study of the first group of students.

Finally, there is no data available to assess the utility of a single course in general problem-solving to students in their later professional lives. A follow-up study, based on a sufficiently large sample, is a project

requiring a number of years. Nevertheless, there are good reasons to believe that the general kind of experience students have in a course in problem-solving will benefit them in their professional lives: There are the signs of rapid social, technological, and employment changes already discussed. There is also input available from such large organizations as IBM, Monsanto, Ralston Purina, and Ford Motor Company: Personnel directors in these organizations unanimously expressed an interest in college graduates with training in problem-solving, design, decision-making, long-range planning, etc. In fact, there is a close correlation between the skills identified by such organizations as desirable in applicants for employment with them, and the problem-solving skills identified by students as important to them. (Cf. Part III, A.) There is perhaps good reason, then, to believe that training in general problem-solving may be useful to a student's later employment potential.

(c) A third measure that can be made of the effectiveness of the course is through pre- and post-testing of language, non-language, and total IQ. It is known that the IQ of an individual is relatively stable, unless that individual undergoes effective cognitive training. The actual pre- and post-test scores of students in the Fall, 1976 class on a standard, group-administered IQ test, are given in the attached supplements. The IQ gains demonstrated by students in the class are eloquent testimony of the presupposed character of general problem-solving in such areas as verbal comprehension,

verbal reasoning, and numerical reasoning.

(d) Although not a true measure of the strict effectiveness of a course, its ability to attract future students is essential. No course can be effective unless it is capable of sustaining the interests of its students, and can attract others. Student interest in the course, as it becomes known to the student body, appears gradually to be increasing. The substantial problem-solving and IQ test score gains achieved by many students may suggest that the course can be useful to students who face, e. g., the GRE, LSAT, MCAT, etc. (In cooperation with the Department of Chemistry, a simulation test for the general problem-solving component of the MCAT was administered to a group of some 70 students. A review session on general problem-solving is planned for students who took the test.)

CONCLUSION

A. Summary.

The practice of higher education has reflected an adherence to a content-based paradigm in which the storage concept of learning has played a central role, along with a view of intelligence as a fixed quantity, a resignation to the academic failure of many students, and a need for recourse to extrinsic motivation. The content-based paradigm has come into conflict with the traditional values it represents: Extrinsic rewards for achieving goals of scholarship have themselves replaced and defined these goals. In part, the paradigm is mistaken myth: Intelligence is frequently a product of education, and not that upon which an education must build. And in part, the content-based paradigm is out of step with changing human needs: It frequently provides inadequate learning experiences for students to live effectively in a world of rapid social, technological, and environmental change.

This does not suggest that students are no longer in need of information, and that the sole focus should be upon the development and improvement of technical know-how. Indeed, there is more information essential to today's graduates than was available or expected of those ten years ago. Technical know-how is sterile without content-based knowledge.

Hence, the problem-solving approach to learning seeks to supplement, not to substitute for, mastery of content. And in this, it seeks to humanize educational practice, by restoring to our day-to-day orientation toward learning, a consciousness of the intrinsic values of learning.

The problem-solving approach to learning, in spite of a long tradition -- born in dialectical self-knowledge, and nurtured by American pragmatism -- is still in its infancy: The teaching and learning of cognitive skills is still an area about which comparatively little is known, and consequently the recent growth of interest in general problem-solving is still innovative and experimental. Nevertheless, colleges, universities, major corporations, and foundations have together become actively interested in curriculum developments involving problem-solving.

My own interest in designing and offering a course in general problem-solving grew out of my work over a number of years. Project C. O. V. E. has made it possible for me to do basic research in this new field, to design and implement a course in general problem-solving over a two-semester period, and to undertake several collateral research projects described earlier, which were partially supported by grant funds received.

The various evaluation methods employed have indicated that the course is effective in a variety of ways.

The learning materials purchased for use by students in the course have been of great utility.

Funding provided for a teaching and research assistant has been indispensable: Miss Kathy Nolan has done a superb job in providing students

in the class with individual attention both in special problems sections, and during her office hours. She has contributed her time and thought in connection with course planning, evaluation, preparation and distribution of flyers, course descriptions, and press releases. She has assisted with film projection, test scoring, scoring of special projects, compilation of resource materials for testing, assessment of students' ability levels, preparation of orders for learning materials, and even miscellaneous typing. She is assisting me in correspondence with other institutions offering problem-solving programs and courses, is helping me to construct follow-up questionnaires for students, and prepare a general inventory of materials to be made available to other faculty for use in other courses. She is currently continuing the work of establishing local business contacts, both to profit by their external suggestions, and to make the course known to their employees. Finally, based on her work in the problems sections, she is helping me to prepare a workbook to model for students both productive and weak approaches to general problem-solving.

B. The Beginning of a National Study of the Place of Problem-Solving in the University.

As was mentioned earlier, the number of institutions of different kinds which are becoming interested in problem-solving training is steadily growing. Few individual faculty or even program directors can be expected to undertake the amount of research and correspondence which is necessary independently to educate themselves in this new field. At the present time, no integrated study of the objectives, content, and evaluation of existing courses and programs in

general problem-solving is available for the benefit of institutions wishing to develop a problem-solving interest.

Assembling, organizing, and examining information for such a national study of problem-solving in colleges and universities in the United States, is a time-consuming but important undertaking. A proposal to complete such a study, and to make the results of the study known in mono-graph form to cooperating institutions and institutions requesting assistance, was submitted with a budget to Project C. O. V. E. Unfortunately, having provided very strong financial support for the problem-solving project, it was decided that no more funds should be allocated for the purpose of such a study. The proposal was then submitted to the NEH-funded Man, Technology, and Society Program, where funds were available only for the design of new courses, a heading under which the proposed national study did not come. The proposal was then submitted to Saint Louis University's Faculty Development Fund, but here again no funds were available for faculty research stipends. I am now seeking external support for the project.

Although a functioning course in general problem-solving has now been integrated into the curriculum at Saint Louis University, the initial work underwritten by Lilly to organize and assess other programs in problem-solving has yet to be completed.

C. The Knowledge Management Double Major of Saint Louis University.

A grant proposal is now being developed to establish a "knowledge management double major" at Saint Louis University, which would permit

interested and qualified students to supplement their traditional majors

with work in one of the following three areas of concentrated study: futures

studies, systems analysis, and problem-solving. The Patterns of Problem

Solving course would function as one of five core courses in this program,

and would introduce students to four more advanced courses in problem-

solving which they could choose to take.

Much time has now been devoted to the formulation of a program

in knowledge management. Such a program expresses in a very real sense

the openness and concern on the part of many institutions today to supplement

the existing paradigm of content-based scholarly learning by an ancient yet

relatively unknown problem-solving orientation toward learning.

Patterns of Problem Solving
Analysis of evaluation results
IQ pre- and post-testing

Instrument: California Test of Mental Maturity (CTMM), Short Form, 1963,
Level 5 (mental age range common to grades 12 - college and adult)

Pre-test results

	(i) language IQ	(ii) non-language IQ	(iii) total IQ
mean	126.29	120.88	127.94

Range: (i) 100 - 138   (ii) 100 - 137   (iii) 115 - 142

Post-test results

	(i) language IQ	(ii) non-language IQ	(iii) total IQ
mean	130.64	127.24	133.41

Range: (i) 119 - 146   (ii) 113 - 139   (iii) 123 - 143

Observations

The above scores relate only to those students present for both the pre- and post-tests. N = 17.

In terms of total IQ, 29.4% of the students demonstrated an increase in IQ score of between 10 - 17 points. 52.94% of the students increased total IQ scores from 7 - 17 points. (The standard error of measurement for these tests is 5 points; hence, these increases are statistically significant.) A total of 82.4% of the students showed some increase in their total IQ scores.

In terms of language IQ scores, 23.5% of the students demonstrated an increase of 11 - 19 points. 35.3% showed an increase of 8 - 19 points.

In terms of non-language IQ scores, 29.4% of the students demonstrated an increase of 13 - 24 points. 47% showed an increase of 6 - 24 points.

It is empirically well-established that increases in IQ scores become progressively more difficult to produce the higher the pre-test IQ mean is. In the present case, the average initial total IQ of students in the class was 127.94. Any increases in

IQ scores beyond the standard error of measurement, given this starting point, were unusual, and were not expected.

The problem-solving class concentrated on problem-solving techniques of specific kinds -- e.g., probability reasoning, use of formal representations, modeling, use of flow charts, decision methods, etc. Skills tested for on the CTMM were not emphasized. (Approximately four class meetings, only, were devoted to the types of problems encountered on the CTMM.) It seems reasonable to believe, then, that the increases detected in IQ scores indicate that general problem-solving skills possess a generalization characteristic. In other words, training in general problem-solving skills appears to improve indirectly a student's verbal comprehension, memory, and quantitative reasoning skills of the kind measured on most IQ tests.

It should also be mentioned that the IQ post-test was given during the last week of classes, before final examinations and Christmas vacation. It is well-known that testing at such times frequently can reduce a student's raw score. In this light, the gains observed are rather more surprising.

Patterns of Problem Solving
Analysis of evaluation results
Pre- and post-testing:
    General problem-solving skills

Improvement in general problem-solving skills was computed as follows:

        (post-test score) - (pre-test score) = improvement on a percentile scale

This score, representing relative improvement on a 100 point scale, was then
analyzed in terms of the percentage improvement of the post-test increase in
relation to the pre-test score.

The mean improvement on a percentile scale was +30 points.   This corresponded
to an improvement of 84. 5% in relation to pre-test scores. In other words, on
the average, students in the problem-solving class improved their general
problem-solving skills by 84. 5%.in relation to their entry skills at the beginning
of the semester.

Patterns of Problem Solving
Course evaluation by students
December 10, 1976

(See evaluation form, attached)

1. 4: 64.5%
    3: 21.4
    2: 14.1   (64.5% positive)

2. 5: 31.3%
    4: 31.3
    3: 31.3
    2: 6.1   (62.6% positive)

3. 5: 50%
    4: 43.8
    3: 6.2   (93.8% positive)

4. 5: 68.8 %
    4: 31.2   (100% positive)

5. 5: 31.3%
    4: 43.7
    3: 25.   (75% positive)

6. 5: 6.3%
    4: 37.5
    3: 43.7
    2: 12.5   (43.8% positive)

7. 5: 38.5%
    4: 23
    3: 38.5   (61.5% positive)

8. 5: 43.8%
    4: 25.
    3: 18.8
    2: 12.4   (68.8% positive)

9. 5: 31.3%
    4: 37.5
    3: 25.
    2: 6.2   (68.8% positive)

10. 5: 31.3%
     4: 25
     3: 37.5
     1: 6.2   (56.3% positive)

11. 5: 68.8%
     4: 18.8
     3: 12.4   (87.6% reg. attendance)

12. 5: 37.5%
     4: 37.5
     3: 25   (75% positive)

13. 5: 50%
     4: 18.8
     3: 31.2   (68.8% would recommend)

N.B. Respondants circling
      5 and 4 were interpreted as
      positive , those circling 3, as
      neutral, and those circling
      2 and 1, as negative.

Remarks. Student response to the course was consistently positive, with the exception
          of item 6, which seems to indicate the pace of the course was somewhat
          too fast for the majority of the students (56.2%).

Course Evaluation

Course_____
Instructor_____
Date____._____

1. Was the course well organized?   most of the time 5 4 3 2 1   seldom

2. Did the course hold your interest?   5 4 3 2 1

3. Did the professor stimulate interest in the course?   5 4 3 2 1

4. Was the professor responsive to students in the classroom?   5 4 3 2 1

5. Did the professor express ideas clearly?   5 4 3 2 1

6. Was material presented at the proper pace?   5 4 3 2 1

7. Did you have adequate opportunities to see faculty or
   t. a. outside of the classroom?   5 4 3 2 1

8. Were the quizzes, presentations, homework, etc.,
   adequate to test the application of knowledge in this course? 5 4 3 2 1

9. Were the assignments pertinent to the course?   5 4 3 2 1

10. Was the assignment load adequate?   5 4 3 2 1

11. How often did you attend class meetings?   5 4 3 2 1

12. How much have you learned in this course?   much   5 4 3 2 1   little

13. Would you recommend this course to a friend?   5 4 3 2 1

14. What is your major?   _____

15. What is your year in the University?   _____

16. General Comments;