THE UNIVERSITY OF MICHIGAN
DEPARTMENT OF MECHANICAL ENGINEERING
AND APPLIED MECHANICS

AUTONOMOUS LEARNING IN THE ENGINEERING CURRICULUM

Final Report

By

Panos Papalambros
Assistant Professor
with
the Contribution and Inspiration of
Jonathan A. Laitone
Late Assistant Professor of
Mechanical Engineering

Research Conducted
under the Spencer Foundation
Seed Grant for Research in Education
to the School of Education
at The University of Michigan

Ann Arbor, Michigan
June 1982

FOREWORD

The ideas and activities described in this report were implemented during a two-year period, from September 1980 to June 1982. The original conception of the research project came from the strong feeling I shared with Jonathan Laitone, that we ought to look at our students as persons with feelings rather than problem-solving machines. We both believed that in engineering education at large, learning is perceived by the students as a need for information processing and assimilation imposed from the outside with little or no involvement of themselves at a personal level. Moreover, in most traditional engineering courses at American colleges, learning is presented as a highly individual activity with hardly any opportunities for group interaction.

At the time, I had already some experience in teaching a senior mechanical engineering design course, so we decided to use that course as our research vehicle. We team-taught that course in the Winter term of 1981, where many of our ideas were tried for the first time. We modestly admitted to each other that it was a great success and proceeded to try to identify our findings more concretely. In June 1981, Jonathan Laitone was killed by an avalanche on Mount Rainier. I had lost a most wonderful friend, but I had retained the memory of our many long-hour, late night discussions. His sharp intellect and refreshing enthusiasm stayed with me. I decided to continue the project by myself and try our ideas again. Dean Joan Stark of the School of Education extended the research support, so I taught the design course two more times, on an experimental basis, with Angus Rogers acting as research and teaching assistant. He had experienced the course as a student the previous time we taught it with J. Laitone. His help and moral support proved very valuable. My colleague J. Whitesell, also a good friend of J. Laitone, participated in many class meetings and his encouragement was instrumental at that difficult time.

The present report gives an account of my present level of experience in what we coined "Autonomous Learning" with Jonathan Laitone. I wish to thank Dean J. Stark and Professor R. E. Sonntag for their support of the project, A. Rogers for his assistance, and all my students of ME460 for proving that, after all, they are persons with feelings, at least feelings positive towards the ideas described herein! Finally, I would like to thank Ed Laitone for finding the strength to recover and make available to me the many notes that we had kept with Jonathan on this project.

Panos Papalambros

Ann Arbor, June 1982

CONTENTS

AUTONOMOUS LEARNING
IN THE
ENGINEERING CURRICULUM

By

Panos Papalambros

Report No. UM-MEAM-82-5

RESEARCH MOTIVATION

As we move into the pragmatic 1980's, it is becoming almost old-fashioned to talk about a person's self-realization and growth of human potential through group processes. The "Me Generation" of the 1960's and 1970's, which flourished in what Tom Wolfe called the "era of every man an aristocrat" [1], is now replaced by a college student body that is preoccupied primarily with acquiring marketable skills and getting a fair return on their tuition money investment. Even the popular "self-help" paperbacks which for many years offered recipes for various forms of personal growth and satisfaction, are now dealing with such issues as personal financing, management, and computer programming. It appears rather clear that society in the 1980's has changed its priorities and perhaps also its ideological orientation.

What is the impact of this apparent change on education? There is general agreement, from Thornstein Veblen to modern neo-marxists--perhaps with some dissent--that education is society's main instrument for ideological reproduction, at least as much as it is an instrument for information dissemination. Although the response time that the educational system has with respect to social changes is not well-defined, we expect that this time is considerably shorter for college education, particularly that offered by the professional schools. That this is the case, is evidenced by the large increase of enrollment in engineering colleges across the country. Thus, with regard to the engineering students of the 1980's we may identify two new trends. One is a stronger interest in learning skills and acquiring knowledge explicitly useful in the marketplace after graduation. Another, though, is the appearance of students that do not fit in the traditional engineering stereotype and who, having drifted into engineering for job security, will still seek a broader intellectual stimulation and a more independent acquisition of knowledge--although not necessarily within the engineering curriculum. We may expect that the increasing number of women enrolled in engineering will further amplify this second trend. The traditional orientation of engineering curricula has been the development of problem-solving techniques. This orientation was challenged in the 1960's and 1970's with questions on the social and political relevance of technology. These questions will probably remain through the 1980's, though perhaps not as vocally. Yet, other types of challenges could be emerging, such as the one expressed by a piece of graffiti on an engineering school wall [2]: "Must we find a solution? Can't we just enjoy the problem for a while?".

Engineering Graduates in Industry

Most engineering schools, despite habitual criticism, give a very adequate--if not very good--body of knowledge to their graduates for use in the industrial workplace.

Engineering graduates do not seem to lack in technical skills as such. Curricular modernization may be sometimes slow, but generally follows the technological developments quite well.

The first real problem that the graduate faces in industry is coping with the organizational structure of modern companies and interacting with an environment that is radically different from school. One quickly finds out that one is a member of a group that must function together and that tasks and decisions are very intimately dependent upon decisions and actions of others. Communication of ideas in all forms becomes of paramount importance. Interpersonal relations and emotional issues tend to dominate rational responses and decisions, or at least affect them to an unexpected degree. Previous education appears to become quite irrelevant. The equations learned with considerable effort over a number of years seem to matter less and less.

A second problem will appear somewhat later. We can state it simply as the need to be able to adapt to changes and advancements in the field. This is of course true for every scientist and professional, but for the engineer it becomes vital when we consider the formidable technological rate of change over a career life of 40 years. The laws of nature may not be changing much, but what we do with them has been and will be changing at a very fast pace.

The above observations are well-known and well-discussed. The question, however, is what do we do, if anything, to provide our engineering graduates with the kind of education that will assist them to deal successfully with these problems.

Nature of Engineering Curriculum

The human potential movement of the two previous decades had certainly some influence on engineering education, particularly in the East and West Coasts. The traditional behavioral psychology had already found its way into engineering, because engineering teachers at large have always been much more interested in the educational process than what is usually assumed outside the profession. Another reason, of course, was its applicability to human factors engineering. The development of humanistic psychology, as exemplified by Abraham Maslow [3,4] and Carl Rogers [5], and the more recent transpersonal psychology with the pioneering work of Andrew Weil [6] and the influence of Michael Murphy's Esalen Institute in Big Sur, California [7], have been noticed and somewhat implemented primarily in the teaching of engineering design.

Design courses, with their emphasis on creativity and synthesis of material from all other engineering courses, have provided the best vehicle for introducing and utilizing ideas from the psychology of education [8]. Relevant articles appear frequently even in trade magazines such as Machine Design and Production Engineering. The split brain theory on the functions of the left and right hemispheres of the brain [9] is now quite well-known at least among design educators. In a recent article [10], Williamson and Hudspeth propose the thesis that: "Educational processes have become dominated by left-brain learning. It is quicker, easier and more measurable than right-brain learning; it fits closer to learning objectives. Advanced degrees tend to select students most successful at left-brained operations, and these students subsequently become educators."

The implications for the nature of the engineering curriculum become now rather evident. The problem-solving orientation of most courses encourages students to guess the "right answer" which the professor has in mind. The students are seldom given the opportunity to formulate their own framework of questioning, posing the problem and providing answers to the problem as they stated it. Encouraging creativity appears to be time-consuming, when the students believe that the answer is well-known and can be efficiently presented by the professor. In fact, many students seem to expect to receive a large flow of information in exchange of their high tuition.

The large numbers of students and the problems of grading lead to classroom formats where the students work individually, assume the sole role of receivers and processors of information and are evaluated on clear-cut, easy-to-grade assignments. Students are hardly conscious of their own thinking and learning processes and they are rarely concerned about it except for the times they may receive low grades.

All these activities involve indeed the explicit, logical, sequential characteristics of the left hemisphere. The illusion is created that, at least in the professional life, the world runs with the left-side of the brain. As Williamson and Hudspeth point out, engineering educators will tend to reproduce themselves with an increasing tendency towards left-brained thinking, as the shortage of faculty and resources continues. In contrast, the problems of engineering graduates in industry that we mentioned earlier, can be addressed successfully with a high degree of right-brained thinking and a guided experience in group and interpersonal processes.

Autonomous Learning

If we propose a definition of modern engineering as the utilization of science for creative design and manufacturing of objects, most teachers and students will agree. The distinct awareness of the need for creativity is actually present in the atmosphere of an engineering college, an acknowledgment of the need for right-brained thinking. Yet, this need goes largely unsatisfied because of the prevalence of conditions favoring left-brained thinking. Thus, the students reach their senior year with an evident lack of experience in creative thinking, as well as in posing problems and looking for solutions that may not exist.

Attempts to rectify this situation have been made, specifically through humanities requirements in the curriculum. Though Samuel Florman suspects that such emphasis on humanities comes in the wake of the "antitechnology" criticism of the followers of Jacques Ellul, Lewis Mumford, Charles Reich and others [11], we would anyway expect a positive influence towards "holistic" thinking. It appears, however, that if such influence is present, it is hardly noticable. Humanities courses tend to be considered by engineering students as just requirements that they ought to dispose of as painlessly as possible. The point though is not to criticize the humanities courses, because similar student attitudes can be quickly found towards most of their courses anyway. What we want to emphasize is, that even the typical humanities courses for engineers do not address the main underlying problem, namely the inability of the majority of the students to relate the object of their learning to their own selves. This problem is most prominent in engineering curricula because of their very nature of dealing with objects, while other curricula, e.g. in humanities, sciences, law and medicine, give at least the illusion of personal relevance. Florman argues well of the existential pleasures that engineers can derive from their profession. Our concern here is more specifically an educational one: to define the problem in educational terms and to study what we may wish to do about it.

We will concentrate on two major theses about learning:

1) Learning is an individual human process by definition. Yet, learning occurs most often in a group environment. Therefore, group interactions must be such as to promote individual learning.

2) Learning should not be perceived as a need imposed from the outside, but it must be experienced at a personal level of involvement. Persons must be able to relate the object of their learning to their own selves.

The learning process that satisfies the above two proposed needs we will call autonomous learning.

We believe that the autonomous learner, in our case being an engineering graduate experienced in autonomous learning, will be able to deal with the kind of career problems we discussed earlier, in a way that is both successful and carrying a high degree of personal satisfaction.

Research Objectives

Assuming that autonomous learning is a desirable process in the engineering education, we want to examine the ways by which this process can be introduced effectively in the curriculum. This is an appropriate ultimate goal of our study, but first we must find how autonomous learning can be enhanced. What are the factors that have positive or negative effects? To what extent can you "teach" autonomous learning, for example by amplifying individual awareness through formal coupling of social and behavioral concepts? Are there measurable quantities that can be used as indicators and what types of instruments should we use to measure them?

Our research orientation is neither theoretical, nor strict in terms of formal practices of social and organizational psychology. Rather, our goal is to get some practical understanding and test some specific techniques that could be used again.

Thus, in the present study, we chose as research vehicle a senior mechanical engineering design course. Design being associated with creativity directly, and design, as a word, being one of the most ambiguous in engineering, we decided that in this course we would create an experimental classroom environment where the process of autonomous learning could be observed and the means of enabling such learning would be studied and evaluated.

CLASSROOM SETTING

To understand the context in which we applied our ideas and techniques, we will present first a short description of the course structure, requirements and goals. Traditionally, this course was defined in the books as a senior level course where the students are expected to work on a design project and integrate knowledge from all areas of the curriculum into a coherent synthesis representing a working design.

Course Structure

The students were required to work in teams, preferably with three members, on a project of their own choice, which all the team members agreed that it was important. The only requirement was that the design should involve some sort of moving parts or a control system.

Approximately three weeks from the beginning of the term, each team had to submit a project proposal conforming to given guidelines: the original need had to be demonstrated convincingly; the technical statement of the problem should be derived from the need and objectives clearly stated; background information, alternative solutions and a timetable had to be included. The proposal was submitted in writing and presented orally to the entire class by all the team members. Progress reports followed at four-week intervals with a final report at the end of the 14th week, all reports accompanied by oral presentations.

The class met twice a week for a period of three to four hours. Usually half of the period was used for a general lecture by the instructor or a guest, the other half being devoted to the projects. The instructor would then act as a consultant to the design team.

No exams or homework was assigned.

The students were expected to fill in the gaps in knowledge of previous required courses by personal study. They also had to become somewhat experts in their chosen project area by learning in whatever way, but mostly on their own, the instructor being indeed a consultant and not a teacher. Many of the students had to go and find "experts" inside and/or outside the university including industrial manufacturers. The ultimate goal of the project completeness was a set of specifications and drawings from which the design could be made readily.

Course Goals

The goal of the course was to give the students an experience of the design process as they would later find it, if they practiced the profession. The difference however from an actual experience would be that it was done in a controlled environment with guidance and benevolent feedback, something they could not much expect in an industrial environment. At the same time, they had to work on a real engineering problem and produce explicit results, so the experience could not be taken as just a game.

When our research project was initiated, our students were told that their section would be somewhat experimental and would serve as a laboratory for educational research.

CLASSROOM ACTIVITIES

Over the three times that we used the design course to pursue our research goals, a very large number of activities took place, not all of them in the same class. In each particular class, the students projected collectively a common spirit and orientation which had varied noticeably. We found that several activities were particularly successful in one class, while they left another class rather indifferent. It is perhaps characteristic of our approach that several of the activities and techniques were introduced and conducted in class, almost on the impulse of the instructor and based on our estimation of how the class felt in any one week of instruction. Feedback from the class and from individual students was a major ,contributing factor to our estimations.

The classroom activities are described here grouped in four categories. The first category contains activities aiming at the generation of an atmosphere of acceptance. We wanted to see the students accept each other, the instructors and the goals of the course, in a personal way and not as an accidental result of university scheduling. This was considered important because the course was a required one and not an elective. The second category contains activities that dealt with the exploration of the self and its relation to the others. Creativity techniques, conditioning and stereotyping are included in this group.

The third category contains activities evolving around the development of communication skills. Finally, the fourth category deals with activities aiming at explicit understanding and experience of learning techniques.

The separation to categories is somewhat artificial with a great deal of overlapping in terms of classification of goals. Also, the activities did not occur temporarily in the order they are presented here. Where timing is thought important, we comment on it. The description of each activity is given together with some theoretical justification as an aid to clarifying our motivation behind using a particular technique or constructing an event. Theoretical background is derived in part from Freedman, Carlsmith and Sears [12], Roberts [7], Schmuck and Schmuck [13], Cartwright and Zauder [14], DuBois, Alverson and Staley [15], Kolb, Rubin and McIntyre [16,17].

Acceptance

The specific goals of the course and the techniques to be employed were outside the normal experiences of the students in their curriculum. The students were taking the course in fulfillment of their degree requirements and, in spite of attempts for preselection through the undergraduate advising, the majority of students came in the class with no knowledge of what it involved beyond the catalog description and hearsay.

Hawthorne Effect

From the first day in class and throughout the term, the students were continuously given to understand that they are special. We explained in broad terms that we were conducting an educational experiment and we asked for their compliance. We suggested that if they did not like the section we could arrange so they go into another section. But once committed, they would be expected to comply and adopt the goals of the course and the special activities. We continuously demonstrated our sincerity, dedication and enthusiasm for our research project, the development of the course and the high value of design in engineering. The classic study by Homans [18] at the Hawthorne plant of Western Electric and subsequent verification demonstrate that benevolent pressure, exercized through the individuals' situation by manipulating their environment, making them special and watching their work closely, has a strong positive effect on compliance and acceptance [12].

Prestige

We made the point to the class that our educational research was actually funded separately and that the results of our study were expected to have influence on departmental teaching policies. The implication to the students was that we had enough prestige to carry the institution's endorsement for what might be perceived as unconventional teaching. The studies of Hovland and Weiss

[19], Aronson, Turner and Carlsmith [20] showed that the prestige of the communicator is an important contributor to the amount of attitude change in individuals [12]. It should be noted, however, that on other occasions we based our activities on strong criticism of the university/departmental establishment, in contradiction to the endorsement we were implying here.

Intensions

Another difficulty in inducing student attitude changes for acceptance of the course goals was to have the trust of the students about the objectivity of our intensions and that we did not have personal gain from the imposed new class situation. This was accomplished in a number of ways throughout the course. First, it was pointed out to the class that our work as instructors was substantially increased by our new method of instruction. Next, we observed that our methods might appear radical to the departmental establishment, so that our positions as junior faculty might be jeopardized. These indicated that our goals were rather counter to our self-interest [12]--which in fact was not exactly a lie.

Discipline and Structure

One of the major risks in conducting a course in an atmosphere of freedom, in Carl Rogers' sense [5], is the development of an impression of chaos. In an engineering project design course, this risk is much higher because there are not even blocks of pages to be "covered" in a self-directed study. Measurable knowledge convertible to tuition equivalent is hard to define. The students may get the sense that nothing is happening. Therefore, it was very important to communicate to the students the existence of an underlying structure which required discipline from both students and instructors. Examples of structures that we used were a rigid set of deadlines for completion of project phases, a date-by-date outline of the term's class meeting activities and a fast pace of events during meeting period. Furthermore, all students were required to be present in class and give an advance notice with explanation in case of absence. Deviation from class rules was accepted by the instructors with great reluctance and as a favor to be returned by some other additional effort. We now believe that this fairly rigid structure balanced well with the often playful atmosphere of many class activities and was a major factor in the acceptance of non-traditional activities.

Dual Instruction

A situation that we had not anticipated at the onset of the project, but which developed in a natural way, was the presence of two instructors in the classroom, each with an apparent, yet subtle, role. The class was told at the beginning that differences of opinion between the instructors should be expected and welcomed. As the course progressed, two events became evident. First, during the presentation or conduct of controversial or unusual techniques by the one instructor, the other one was a strong source of reinforcement which served to carry more conviction to the class. Second, criticism and dissonance were also voiced, thus increasing the sincerity and credibility of the exchange. It often appeared that one instructor would play the role of the playful, unconventional student-like person, while the other instructor would play the role of the responsible, down to earth professor who is making certain that everything done in the classroom is legitimate. Clearly the instructors' personalities contributed to this role-playing, yet it was quite evident from the student evaluations that both roles were considered important, complementary, and adding security to the class. In fact, it was amusing that only one out of approximately 80 students suggested in the evaluation form that both instructors should go back to California and try their ideas there!

Grading

We stated at the beginning of the course that the grades would be assigned at the end of the term during a joint conference of each project team with the instructors. Each student would propose his/her personal grade and that suggested for each other member of the group. Then the instructors would give their own opinion and discrepancies would be resolved through group discussion.

To clarify the grading guidelines the students were asked to make lists of grading criteria. During a class period, early in the term, we decided collectively on five (or ten) major criteria that we were going to use in the evaluation of their work. Essentially we made a contract that since the students had chosen the criteria, they would abide by them and do their best to achieve high grades.

This system worked very well. Each time the course was offered, the students selected essentially the same criteria. At the end of the term, they generally tended to undergrade themselves relative to the instructor's opinion. There was one case where substantial overgrading was actually demanded adamantly. This awkward situation (which was probably a result of cultural background) was resolved by an agreement that the instructor would consult with some of his colleagues to insure that the grade was unbiased before making his final decision.

The grading system described here was successful in meeting a number of challenges. One challenge was the individual grade of a student who was expected to work very intimately in a group and whose tangible output was a group project report. Another challenge was reducing the authority-figure stereotyping of the instructor with the power to make or break, to one of a wise and experienced equal. A third challenge was to put an honest foundation for the teams' joint work, without cover-ups of the non-contributors and lesser recognition of the true contributors.

The Grading Hoax

In the middle of the term, we announced one day that the department's chairman had intervened and asked the instructors to "do their job," which was giving grades to students. The collective grading procedure would be cancelled and a specific grading formula with weighting factors would be used instead. We allowed no discussion and expressed no personal opinions. In the following class period, we asked the students to record their feelings and then we discussed them in class. Finally, we revealed the hoax and had a general class discussion--only two out of 24 had suspected the truth.

Apart from one person that got extremely upset (and we had to reveal the truth earlier personally to relieve the anxiety), most of the students accepted the change with rather strong emotion but resignation. We first thought that this was typical student conformity. Yet, to our surprise, in the final discussion, it became clear that the majority of the students expected that we would proceed with our original plan. They believed that, though we might not have formal group grading, we would still keep our contract, ellicit opinions and just tell the chairman that we complied to his request!

This event convinced us that we had certainly won the trust of the class and we were operating as one group with common goals.

Card Matching

This event was designed for the first day of class to force the students to get to know each other as something more than the occupants of adjacent seats.

A number of cards equal to half the number of the persons present in the room was torn into two pieces. Each student and instructor picked a piece and roamed around the room to find the matching partner. Thus paired, the individuals were given five minutes to exchange information about themselves, specifically requested to include favorite music, sports and books. The class reconvened and each person presented his/her mate to the class.

This activity was somewhat time-consuming. The following time that the course was offered, we simply instructed the students to walk over to someone they did not know and start the exercise from there. In both cases, this initial breaking of ice helped in the subsequent formation of groups.

Formation of Groups

There are three main ways in which groups are formed [14]. In the deliberate formation, the original impetus for formation derives from the desire to accomplish an objective, as for example problem-solving and social-action groups. In the spontanous formation, people expect to derive satisfaction of needs by associating together, as for example friendship cliques and social clubs. In the external designation formation, certain people associate because they are treated in a homogeneous manner by others, as for example groups based on race, sex or profession.

In the classroom, groups tend to be formed deliberately, often by assignment. Yet in most situations, some mixing of the three categories is inevitable. Moreover, for our goal of exploring autonomous learning, we believed that the groups should be balanced in their causal formation, as well as balanced toward each other.

Thus, group formation was accomplished using the following strategy. The first day of class the students responded to a written form with questions on their background, skills, interests, work experience and future professional plans. The asembled forms were made available to the class as a data base. Students were told that they must have completed their design team groupings within a certain date, approximately after three to four class periods. We explained that the effectiveness of a group in problem-solving increases with the higher diversity in member skills and backgrounds, while at the same time the project topic would have to emerge by concensus. In a subsequent class period after we let them talk for an hour with ourselves moving around the room facilitating discussion, we had them divided in two groups of similar interests in project topics. After that the discussion continued within each group with further subdivisions until all students belonged to a three-member group. This approach was used to encourage deliberate and spontaneous formation and strongly discourage external designations. In one case where we allowed a group consisting of foreign students alone to form, we found that it was less effective and created a number of problems. On the contrary, the presence of foreign students in groups of American students appeared to stimulate the group processes and have beneficial effects. Women were a small minority and we observed that they always sought to join with male groups rather than form a predominantly female group. The presence of women students also appeared to stimulate group processes.

Feedback

Perhaps the most important technique that we used in generating an atmosphere of acceptance was our continuous solicitation of feedback. Throughout the term, at the end of each event or class period, or argument, or any other significant instance, the class as a whole discussed and appraised what had happened, how useful they found it for themselves and their project work and what were their suggestions for improvement. Instant feedback was experienced in both directions: from the students to the instructors and the other students; and, from each instructor to the other instructor and the students. Open, benevolent criticism was considered a favor towards the person criticized. In fact, criticism could be both positive and negative. On some occasions, at the end of a guest lecturer's presentation, we would offer as a reward for his/her efforts, a class critique on the presentation in terms of style, content and so on. Our colleagues subjected to this, considering it a unique experience!

Exploration

In our definition of autonomous learning, we emphasized the importance of group interactions and the personalization of the learning experience. To enhance the students' ability to deal with these two aspects of autonomous learning, we utilized techniques aimed at exploring personal characteristics, ways of thinking and ways of reacting to stimulations from the group environment. Clearly, there is a very large number of factors that could be studied in this context. We decided that we should primarily concentrate on two areas: first, factors associated with creative problem-solving and typical blocks encountered in facing novel situations; second, factors associated with the development of effective groups within the framework of an organization, such as the class or the workplace. An anthology of techniques to break through blocks was compiled by James

Adams [21]. A number of useful exercises on interpersonal exchanges comes from transactional analysis [22,23,24]. These provided some guidelines for class activities.

Brainstorming

Alex Osborn's well-known technique of brainstorming [25] has become almost a household word. Yet, most people mistake brainstorming for just sitting around and exchanging ideas. Osborn had four main rules: generation of large quantity of ideas, deferment of judgment, encouragement of wild ideas and building upon modification of the ideas of others. The rules most often not followed in inexperienced groups are quantity and suspension of judgment.

In our brainstorming sessions, we presented some theoretical background on creativity and then divided the class in large groups of six to eight persons. A typical problem was given, such as "Give at least 50 uses for a common lead mechanical pencil within five minutes." The exercises were repeated for groups of three, two and then individually.

Two observations were made. First, after an initial period of hesitation the group's output increased substantially both in quality and in quantity. Second, the individuals were able to generate a comparable number of ideas, but only after they had already experienced the process in the group. The students felt that they had not expected themselves capable of individually generating so many ideas. At the same time, the groups acknowledged that the major advantage of the group work was the injection of "trigger ideas," by one group member, at the time of low output, which subsequently precipitated a large flow of ideas from the rest of the group. This is a well-observed phenomenon [26].

Student evaluations indicated that brainstorming often became a routine technique in their project deliberations. It also appears that the main utility of brainstorming came from the enforced suspension of criticism within the group and the allowance of creative participation by all members and not just the most vocal ones.

Synectics

The method of synectics is considerably more complex than brainstorming and the full details can be found in a description by Gordon [27]. The operational utility of synectics is based on "cheating" one's consciousness into overcoming blocks to creative thinking, normally excluding novel solutions from consideration. We employed primarily the fantasy analogy, as the mechanism for metaphor.

The technique had varying success. One class found it rather ineffective, another one though considered it as one of the best experiences in the course. As Gordon and others have pointed out, the uncertainty involved in the explanation of the mental processes in creative thought, makes it difficult to design a synectics section that is always successful. From our experience, one of the favorable factors was the apparent belief of the session participants that the problem could indeed be solved and that they possessed the intellect to generate solutions better than what was attempted before.

Scripting and Stereotyping

Scripting is used in transactional analysis (TA) to uncover the origins of stereotyping in society. People design their own behavior according to a role determined by a perceived psychological script [23]. The world is a stage where every drama has three basic characters: persecutor, rescuer and victim [28]. People use these roles in constantly interchangeable manners. The dramas played can be constructive, destructive or with no end. TA techniques are expected to assist in breaking up the negative scripts, turning off destructive messages and allowing the person to become more autonomous and more in control of his life changes [23,24].

As a technique to expose scripting, we asked the students to write a script about their educational experience and present it with a characterization as a motion picture or a TV show. The class presentations were quite spirited and pointed out several negative roles that the students had assumed during their schooling. Subsequent discussion centered around how they could change these roles if they wanted.

While scripting is role-playing imposed from within, stereotyping is also role-playing but imposed from the outside. We asked the students to make lists with words, such as "Men are ..." and "Women are ...," to explore sex stereotyping. Comparing the lists it became clear that though some characteristics were distinctly different, most were actually common--particularly when female responses were included in the predominantly male responses. Then the students were assigned to search in magazines and find at least three advertisements with people on male and female stereotypes. At the next class period when this information was brought in, there came the overwhelming conviction that the sex stereotyping in advertising was quite removed from reality and was based on qualities that the students had actually found common for both sexes, such as suggestiveness, efficiency and executive power.

A final exercise on scripting and stereotyping consisted of asking the students to work in teams of four or five and prepare a skit with roles assigned by the group to best match each individual's personality. The skits were acted out in class at a 10-minute length. It was an amusing yet quite open way to express how the group perceived each member in terms of qualities, personality and role. As an example, one of the instructors was assigned the role of Godfather in a Mafia extermination trial (the instructor was an original native of Greece)!

Ego-States

A blending of E. Berne's transactional analysis [29] and F. Perl's Gestalt therapy [30] was developed in the form of "egograms" for a practical application of those ideas [22]. This popularization for "self-therapy" is perhaps outdated today, yet still useful for a first initial exploration of the dynamics of human interactions. A large number of communication blocks between individuals can be explored simply through the parent-child-adult comparison triad.

A number of exercises aiming at exploring one's attitudes through an ego-state description were conducted throughout the term. For example, after the grading hoax, students were asked to describe in writing their ego-state at the time of initial reaction and again one day later. Another example, was ego-state analysis of the group members during project meetings.

During discussions on ego-states we focused on how to achieve the adult state and how to induce others in the adult state for meaningful interactions. The students soon developed skills, and in many groups it appeared quite effective to just invoke a question of ego-state in order to settle arguments and start afresh.

Conceptual Blocks

The various types of conceptual blocks were discussed together with exercises, mostly from Adams [21]. Apart from the utility of this discussion for general awareness, it was also helpful in developing a common "language" in exploring subsequent difficulties in the specific design projects of the groups. Most of these exercises are discussed in [21] and are not repeated here. The ego-state model was used also to face blocks in problem-solving. For example, the adult ego-state is best for communication in the short term, but not necessarily for solving problems that suggest emotional involvement. The "Constant Adult" [23] is more object-oriented than people-oriented. Engineers tend to be in that state and create sterile professional relationships with serious communication blocks in the long term.

Conceptual blocks are often generated by what is called contaminated thinking in transactional analysis. A feeling or a prejudice is expressed often enough and with vigorous conviction, that it eventually takes on the illusion of absolute fact. The history of science, but also everyday engineering, is abundant with such examples. The exercises on stereotyping were used as examples of prejudices. Later on, similar prejudiced thinking was identified in the evolution of the group design projects.

Time Budgeting

People tend to structure their time in ways that reflect their attitudes and ego-states. According to transactional analysis there are six ways of structuring time: withdrawal, rituals, pastimes, activities, games and intimacy. Recognition of personal time-structuring is a vehicle towards a controlled desired change and achievement of higher autonomy. A controlled balance among awareness, spontaneity and intimacy is, according to Bern [31], the characteristic demonstrating a truly autonomous person.

The students were asked to prepare a time-budgeting sheet of their everyday activities during a typical school week. Follow-up discussions dealt with the nature of the personal time-structuring, its implications and the potential for desired changes.

Group Leadership

The issue of leadership is central in the study of group processes and group dynamics and is treatd throughout the literature and in most of the cited references.

Our approach to the specific question of leadership in the design teams was simple. Each team member would assume the role of leader for a specified amount of time coinciding with completion of certain tasks. Usually each student was group leader for a third of the term. The order of service was decided by the group. The leader's role as described by the instructors in class handouts was as follows:

1. The leader is the person responsible for making things happen. He arranges for meetings, ascertains that

each group member has a clear assignment between meeting times and enforces discipline.

2. The leader is the liaison between group and instructor. If the group does not function properly, the leader must seek assistance from the instructor. However, he is vested with enough authority to enforce discipline.

3. The leader is not a decision-maker. Instead, he facilitates decisions, mediates, suggests and encourages. However, he holds the members accountable to the completion of the agreed upon decisions.

This leadership structure has several advantages. Each class member has the opportunity to experience influence and personal control over others, a situation that many non-aggressive students hardly ever find themselves into--until seniority brings it much later in their professional life. We observed that the more timid persons actually worked much harder and more effectively during and after their leadership period. In the few cases where this did not occur, the dominant personality of the group assumed the leadership role informally and so group function was preserved. Another advantage is that leadership is not associated with personal motives for power, but rather as goal-directed influence. Bass calls this "effective leadership" [13,32] and it is particularly important in the classroom where the teacher's personal influence is overwhelming. A third advantage is in fact the dispersion of influence structure and indeed a facilitation to the instructors' supervising and administrative role. A fourth advantage is the transfer of responsibilty and the need for self-control on behalf of the students.

We can safely state that this mode of leadership was accepted by the students and found very effective. Performance of the leadership function, formally or informally, was considered as one of the parameters to be graded.

Group Size

The three-member group was found to be optimal, at least for the design teams. Two-member groups tended to get into unresolved arguments. Four or five-member groups tended to de-emphasize the presence of the less aggressive members and also to reduce the total work output per student. A study by Stephan and Mishler [12] shows that both the total and the differential amount of communication drops substantially for groups larger than four.

Communication

Many of the techniques described in the previous sections had a direct influence on the amount and quality of communication among members of the class. The importance of proper communication and the skills required for it cannot be overemphasized. In this section, we describe our efforts specifically aimed at improving the students' skills as communicators.

Oral Presentations

The project proposal and the three reports for the project were required to be presented by each team to the class. All team members had to participate. The presentations were formal events employing visual aids and with tight time limitations. The formal part of the presentation concluded with a question and answer period. Each formal presentation was then followed by an informal critique period, where the class and the instructors criticized each speaker for presentation content, delivery, visual aids, mannerisms and so on. We had all made an initial contractual agreement that such criticism was explicitly and solely for the benefit of the criticized person. The point was made that only friends will openly criticize one's behavior. These experiences were found universally very valuable and students considered them one of the major benefits of the course. Most students at the final project presentations had achieved professional quality of presentation that we, as instructors, do not usually enjoy at scientific meetings.

Nonverbal Communication

The oral presentations served well to demonstrate the importance of nonverbal communication and body language [33]. Very often we were able to identify motions and facial expressions that communicated unspoken words or contradicted spoken statements. These ideas were also used when we studied how groups arranged themselves during working sessions, how they were holding their arms and so on.

Design of Experiments

Engineers are often required to demonstrate their ideas in some tangible way. Communication of physical principles often requires ingenuity. Thus, we assigned an exercise where the students had to prepare individually a simple experimental apparatus which could demonstrate in class a law of nature. A variety of clever experiments were devised. The demonstrations were followed by a lecture on the design of scientific experiments. This was rated by the students as a useful learning activity.

Written Reports

Great emphasis was placed on report preparation. Detailed instructions were handed out and discussed and the students were essentially requested to produce a piece of work that was the epitomy of their college studies, something they could use as proof of their abilities in their interviews for employment or graduate school. A final draft was turned in to the instructors for comments before the typed copy was submitted. The reports also served as basis for grades and as a vehicle for enforcing discipline in the production of measurable course work.

Interpersonal Communication

A group of exercises specifically aimed at interpersonal communication was used, based on Kolb et al [17]. The objectives were: understanding the barriers to effective communication and exploring the process of their elimination (e.g. egograms), active listening as advocated by Rogers [16,34], increasing sensitivity to nonverbal communication and giving feedback to personal communication styles. The details of these exercises can be found in [17].

Learning

All the techniques and activities described until now were implemented on the belief that they contributed to conditions for autonomous learning. However, as we stated early in this report, learning is by definition an individual activity. In this section, we describe certain instruments that we used to help students explore their personal learning patterns.

Solver-Listener-Observer

This technique, adapted from Woods [26], was the following: Relatively simple problems were handed out to teams of three members and each team member took in turn the role of Solver, Listener and Observer. The Solver embarks at the solution but he is thinking aloud, continuously explaining to the Listener what he/she is doing but not necessarily why, unless that is part of the thinking process. The Listener follows the thinking, asks for clarifications but does not attempt to solve the problem himself. The Observer remains totally silent and keeps a record of the exchange with particular attention to prevailing ego-states.

The exercise is structured around problem-solving. This is intentional because we follow here the hypothesis, as proposed by Kolb et al [16,17], that the characteristics of learning and problem-solving can be conceived within a single process. Kolb's four-stage cycle of the learning process assumes that concrete experience is followed by observation leading to formation of abstract ideas and in turn to hypotheses for testing. The cycle reoccurs continuously as testing, experience and observation are compared against each other.

In the above exercise, one interesting pattern that developed was the relative position of Solver and Listener depending on their perceived expertise in the particular problem area. A certain "tyranny of experts" was evident: the Solver talks with authority, "telling" the Listener the way to solve the problem. In the case, however, where the Listener, through perceptive questions, was thought as a better expert, then the authority roles were reversed and the Solver tried to solicit ideas by implication. This pattern, when developed, was counterproductive. Most successful exchanges were conducted at the "adult" level.

Learning Style Inventory (LSI)

This is a specific instrument developed by Kolb to measure the strengths and weaknesses of a person as a learner in the four stages of the learning cycle explained earlier [16,17]. The test was administered and then the scores were interpreted and discussed. Since we were concerned with the type of learning without evaluation, the class discussions included how the results of the inventory correlated with the individual's own perception as well as that of his/her classmates.

An interesting result was that from the class sample there was no correlation of the scores with the learning style that Kolb considers characteristic of many engineers. We used the LSI subsequently in a sample of 200 engineers, again with no particular correlation results with those of Kolb. These results are discussed later in this report.

The test itself generated a substantial interest to the students. However, we were unable to complete the group meeting exercises associated with the LSI and follow-up at a later date. So, the utility of the instrument for the class is still undetermined.

Decision-Making Process

Autonomous learning is closely related to decision-making in a group. Learning as a need involves a decision, and the person must feel part of decision-making process or at least understand how decisions are reached at a personal, group and organizational level.

One introductory exercise involved a Guided Design session of a fishing trip that resulted to isolation on a small island and the need for a series of decisions by the stranded group for survival [35]. This informal introduction was followed at the next class meeting by a lecture on the formal decision analysis discipline of Operations Research.

A second exercise was conducted based on the decision-process flow chart by Vroom and Lago [16,17,36,37]. The goal of the exercise was to use the formal model to analyze actual organizational decision situations. The exercise was generally useful, though somewhat inconclusive because of differences in the interpretation of certain assumptions of the model. However, the students found that the model does describe fairly the style of group decisions they made for their design projects.

Learning Checklist

The students were asked to create two lists of approximately 20 items each, describing the factors that have positive and negative influence on their learning. Factors should be considered from school, family, relationships and social environment.

This exercise was designed to force the students to spend some time reflecting on their learning experiences. The lists contained generally known factors, with the usual range of opinions where the same factor is considered by some positive and by some negative, as for example a competitive environment, or a demanding teacher. An interesting result that is often forgotten in engineering classrooms is the effect of the actual physical conditions in the classroom such as temperature, lighting, ventilation, windows, seating, colors and acoustics.

LEARNING STYLE INVENTORY

We mentioned in the previous section that the Learning Style Inventory (LSI) developed by David Kolb [16,17] was used as a classroom instrument, though it was not completely explored. The scoring of our students on Kolb's Learning Style Type Grid did not show any correlation with the Learning Type that Kolb associated with engineers. Our sample was small (14 subjects), but more importantly, we administered the instrument during the end of the term, when our students were already systematically exposed to our techniques on autonomous learning. Therefore, we considered that the instrument results could be biased.

In order to obtain some further evidence of LSI°s effectiveness, we called for the cooperation of a number of faculty in the Department of Mechanical Engineering and Applied Mechanics and we were able to give the instrument to approximately 200 undergraduate students, the majority of them in mechanical engineering. The data reduction was obtained using the MIDAS statistical analysis package. In this section, we present some of these results with a preliminary interpretation.

According to Wolfe and Kolb [38] academic field orientations correlate with thinking indices as in Figure 1. In this figure, the scores were obtained from college faculty and it is interesting to observe that they correspond well with our earlier contention that engineering faculty tend to have very strong left-brained

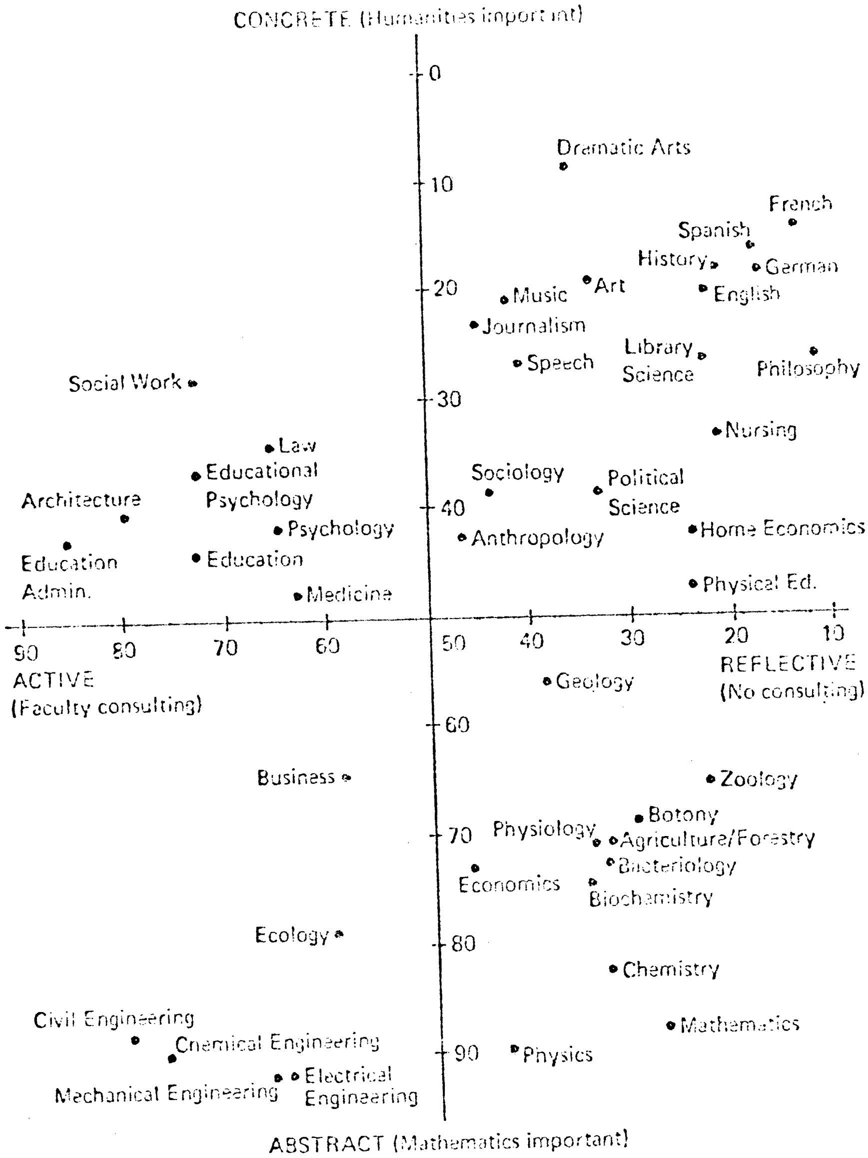

Figure 1: Concrete/Abstract and Active/Reflective Orientations of Academic Fields Derived from the Carnegie Commission Study of American Colleges and Universities (reproduced from [38])

thinking. Though the indices used were created ad hoc, Wolfe and Kolb consider them as reliable indicators.

The LSI correlations with academic and professional orientations, as found by Wolfe and Kolb, are given in Figures 2 and 3. From Figure 2 and some subsequent studies, Kolb suggests that undergraduate education is a major factor in the development of learning style. The question of whether people choose fields that are consistent with their learning styles and/or conforming to the learning norms of their field is still open. Other studies on the accentuation process within a field [38,39,40] were not particularly conclusive, except to show that "learning experiences that reinforce learning style dispositions tend to produce greater commitment in career choices than those learning experiences that do not reinforce learning style dispositions" [38]. From Figure 3, the learning dimensions for the five functional groups (marketing, research, personnel/labor, engineering, finance) were measured by the LSI, all groups being members of a midwestern division of a large American industrial corporation. We observe a significant shift in the thinking/learning orientation of the engineering group compared with the academic picture in Figure 1. However, it still remains in the convergers quadrant of the grid. We may interpret this as indicating that the realities of the industrial environment produce a shift towards more right-brained thinking and a more balanced thinking/learning process.

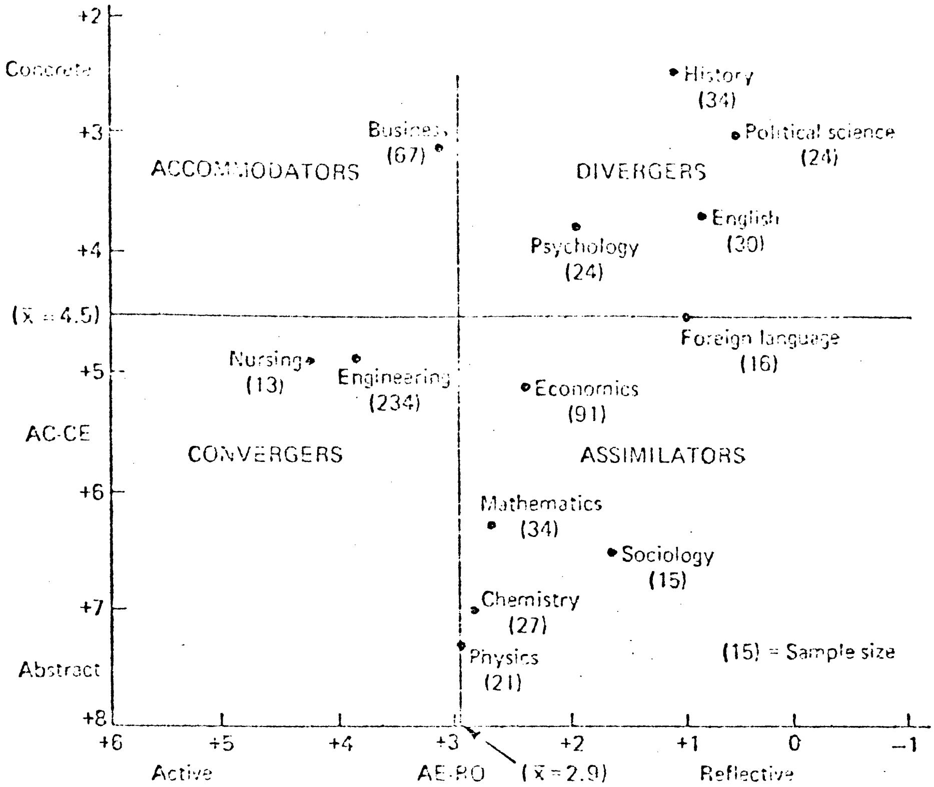

Figure 2: Average LSI Scores on Active/Reflective (AE-RO) and Abstract/Concrete (AC-CE) by Undergraduate College Major

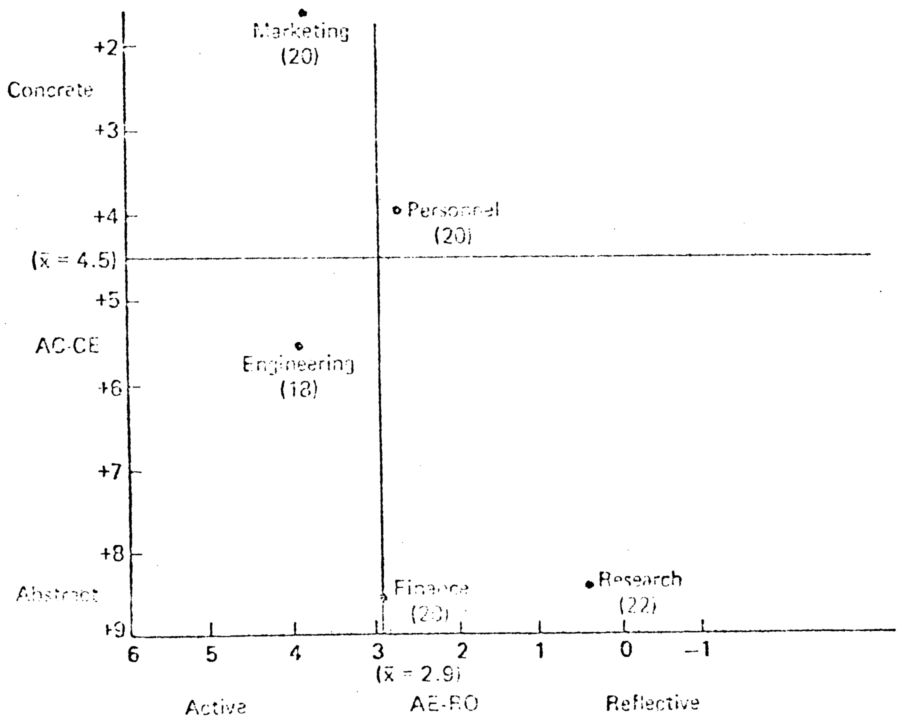

Figure 3: Average LSI Scores on Active/Reflective (AE-RO) and Abstract/Concrete (AC-CE) by Organizational Functions

(Reproduced from [38])

Some results of our own study are shown in Figures 4 to 7. Figure 4 shows the apparent evolution of learning styles as the students progress through their studies. The mechanical engineering students appear to start from the assimilators quadrant and progress towards a rather balanced position among the four styles. Non-mechanical engineering students (mostly other engineering disciplines and business) have a similar trend but more pronounced and clearly towards the divergers quadrant. Figure 5 shows the LSI evolution through the curriculum for male and female students. The same tendency is observed, i.e., a progress from assimilator style to diverger style. This is more pronounced for women. In both figures, we see that the differential change is higher during the first two years, with an exception of the non-mechanical students at the senior year.

The correlation with career orientation was explored and the results are shown in Figures 6 and 7. We observe a clear bias towards the diverger type. This contradicts Kolb's results in Figures 2 and 3. Except for research, which remains in the assimilator quadrant, all others are substantially different from Kolb's study. This is at least the preliminary finding without accounting for possible biases in the data. Women students have a stronger tendency towards the diverger type than men, but they are both in the same quadrant.

We do not consider these results conclusive at this

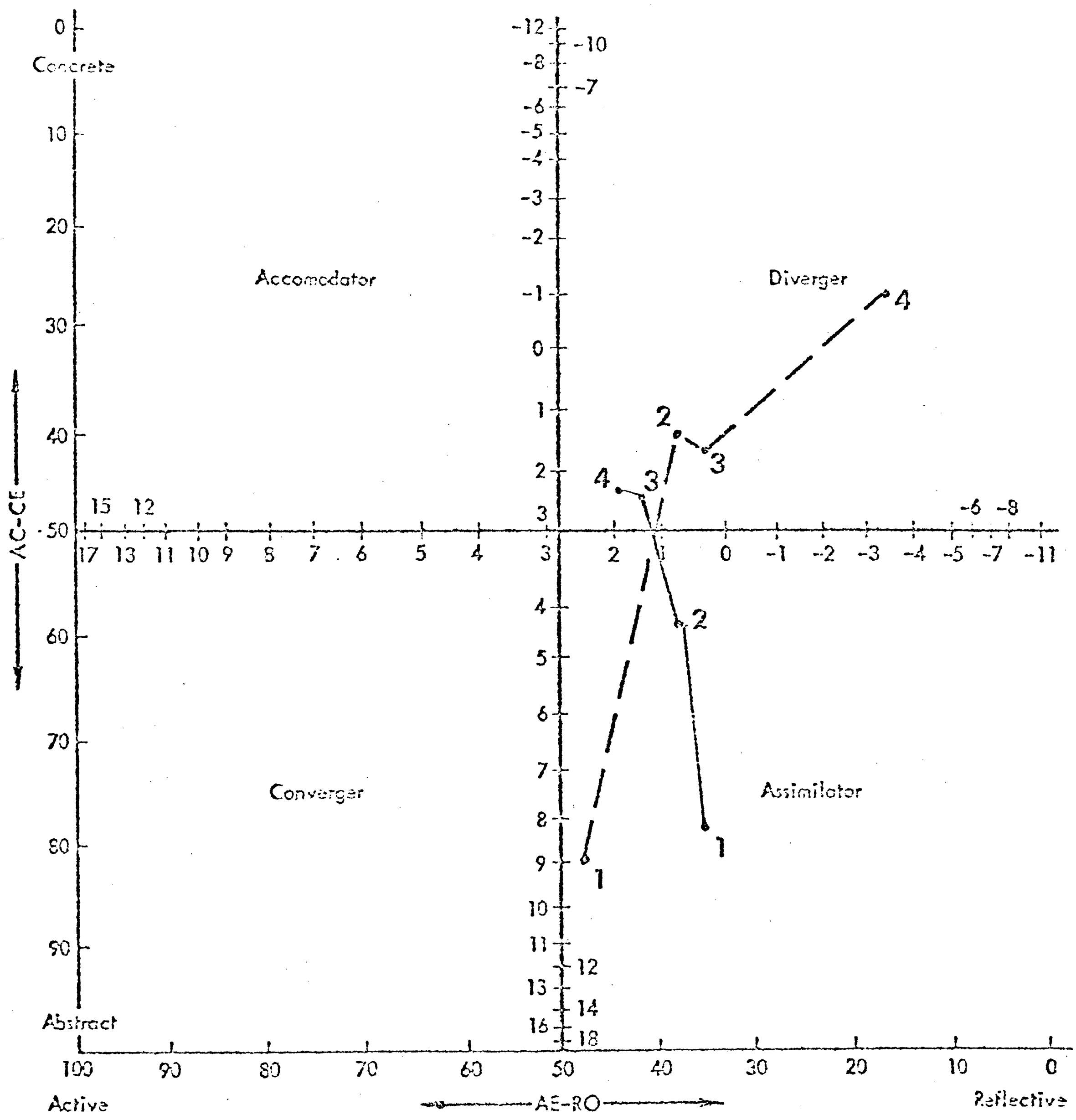

Figure 4: Average LSI Scores at Different Class Levels for ME and non-ME students

ME = solid line NON-ME = broken line

1 = freshpersons
2 = sophomores
3 = juniors
4 = seniors

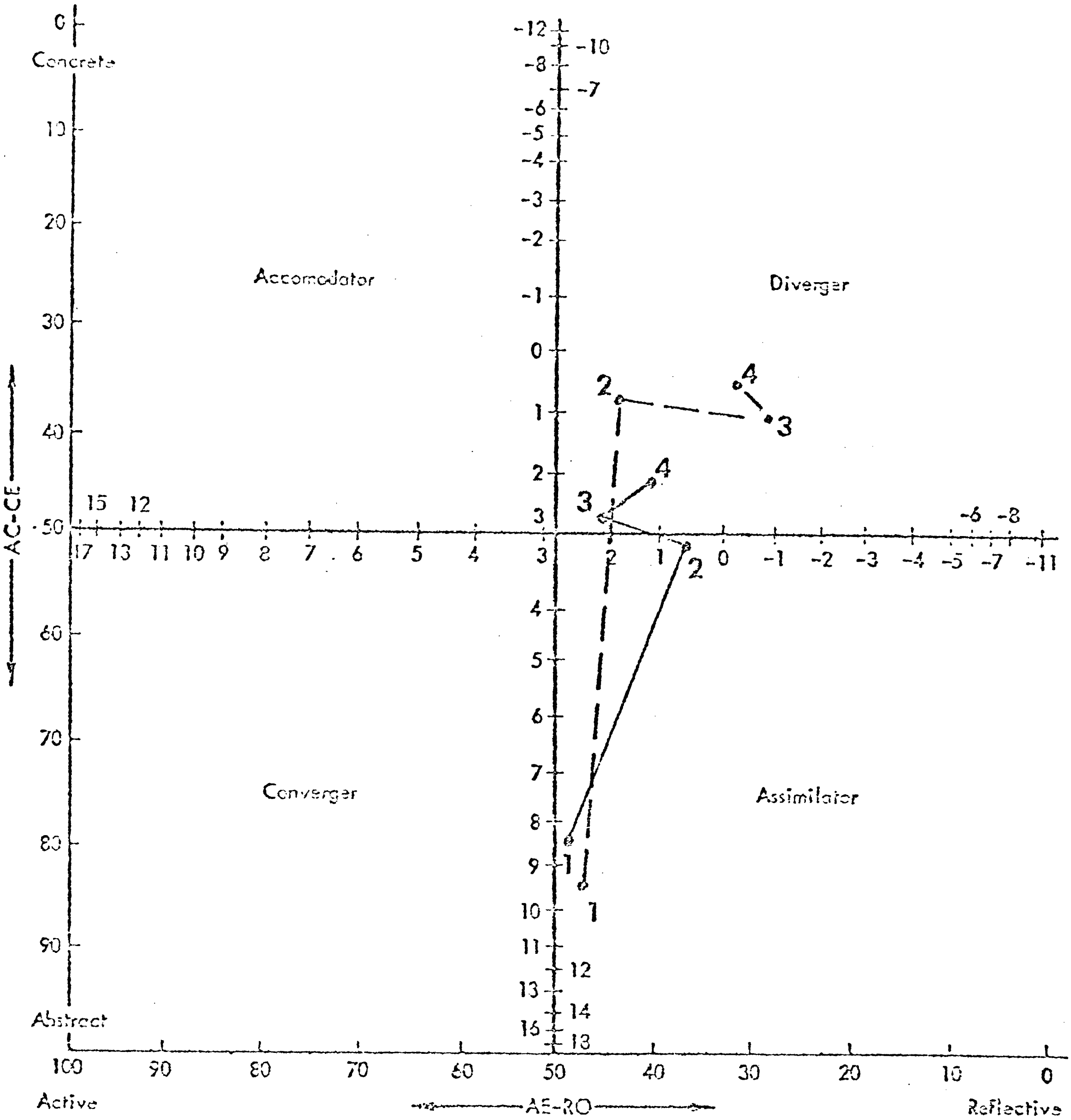

Figure 5: Average LSI Scores at Different Class Levels for Male and Female Students:

Male = solid line Female = broken line

1 = freshperson 2 = sophomore
3 = junior 4 = senior

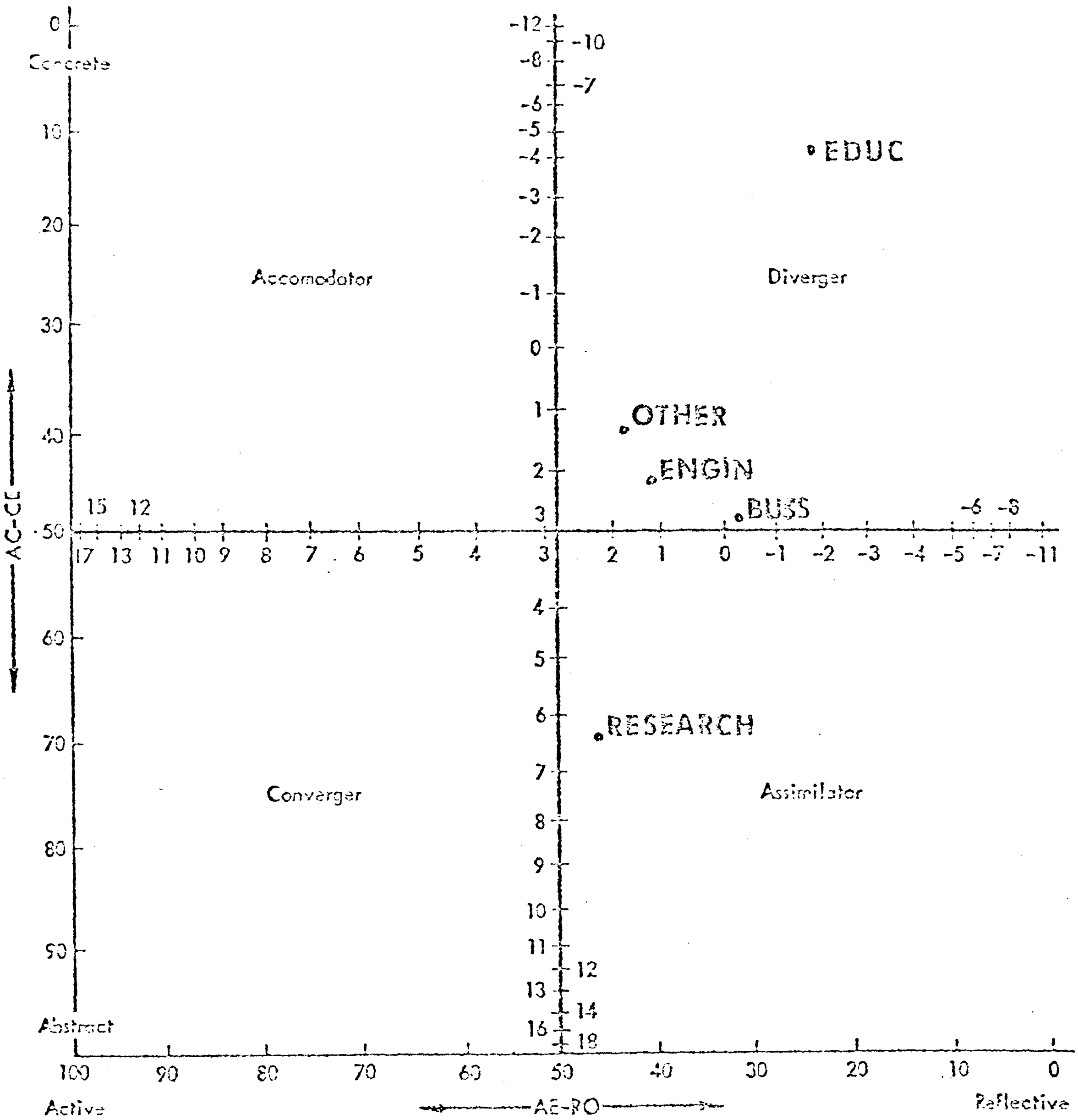

Figure 6: Average LSI Scores Vs. Career Orientation of engineering students

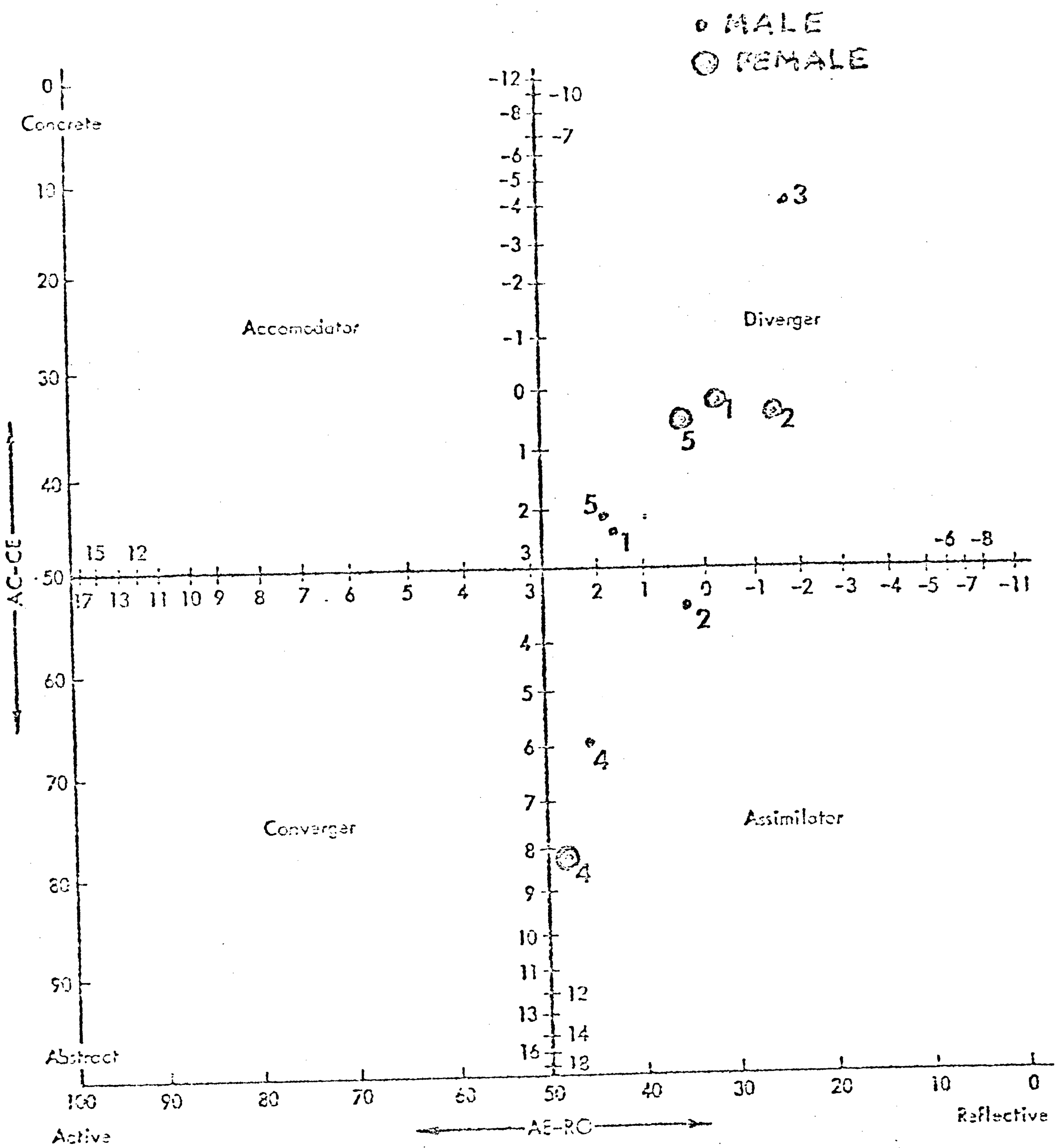

Figure 7: Average LSI Scores Vs. Career Orientation and Sex of engineering students

1 = Engineering 3 = Education 5 = Other
2 = Business 4 = Research

point, but we may suggest certain interpretations of the data.

1. The assimilators dominant learning abilities are abstract conceptualization and reflective observation. This person is more interested in concepts than in practical use of theories. The style is characteristic of the basic science and mathematics. Our curriculum in the first two years is indeed quite biased in this direction. Apart from the required basic science courses, the engineering courses are also mostly theoretical. The students apparently do not escape this influence on their learning.

2. The divergers style is strong in concrete experience and reflective observation. A person with this style performs better in situations that call for idea generation and open-ended problems. The style is characteristic of individuals in humanities and liberal arts. Yet, here we see that engineering students appear to be very strong in this learning style. This is also contrary to the contention that our engineering students lack in creativity, imagination and general right-brained operations. We believe that there is some explanation for this contradiction. First, we should note that the typical Michigan undergraduate engineering student comes from a cultural background associated with families with farming, blue-collar and white-collar vocations. The impact of the college education at large, the college environment and even the life in Ann Arbor have profound influence on their

thinking. In a way, these students become relatively more cosmopolitan, new avenues of thought and experiences are opened to them and thus in spite of their specific curriculum, they become much more skillful and articulate in novel situations. Second, we should note that upper class level courses (such as our own design course) out increasing stress on the concrete experience (e.g. labs, field trips) and the fact that engineering does not give single, undisputed solutions. In effect, our curriculum may not be as "hostile" towards right-brained thinking as we may have assumed. Finally, in the upper class students we see the influence of experiences in summer jobs, out of state travelling and general worldly experiences that point out the diversity of environment, attitudes and approaches to problems.

We may conclude the discussion on the LSI by suggesting that further research and experimentation is necessary in order to understand better the influence of the curriculum structure on the dimensions of autonomous learning as measured by the Learning Style Inventory.

CONCLUSION

The events, activities and techniques that we described in this report are mainly those that we believe may be duplicated, at least in their essential characteristics, to create a classroom environment that will promote autonomous learning and make instruction more enjoyable for both students and faculty. Admittedly, it is not a simple matter of implement them in every course. The pressures for information transfer in the lectures are always present and cannot be ignored. However, it is the underlying philosophy that must be promoted more actively. Perhaps, only some of the activities described here could be implemented in any one course. It is also true that a design course is particularly suitable for such exploration.

We hope that our experience in the conduct of this research will be beneficial not just to ourselves, but also to our colleagues and future students. We have not attempted to settle issues but rather to stimulate ideas and indeed to provoke arguments, to both students and faculty, about what, after all, is engineering education.

REFERENCES

1. Wolfe, T., "Stiffened Giblets," in In Our Time, Maple-Vail, Binghampton, New York, 1980.

2. Haan, M. N., and Hammerstrom, R. B., Graffiti in The Big Ten, Warner Books, New York, 1981.

3. Maslow, A., The Psychology of Science: A Reconaissance, Harper & Row, New York, 1966.

4. Maslow, A., Towards a Psychology of Being, Van Nostrand, Princeton, New Jersey, 1968.

5. Rogers, C. R., Freedom to Learn, Charles Merrill, Columbus, Ohio, 1969.

6. Weil, A., The Natural Mind, Houghton Mifflin, Boston, 1972.

7. Roberts, T. B. (ed.), Four Psycholoqies Applied to Education, Halsted Press, 1975.

8. Wheen, R. J., "The Nature of a Design Philosophy," Engineering Education, Vol. 69, No. 2, November 1978, pp. 201-205.

9. Ornstein, R. E., The Psychology of Consciousness, Harcourt Brace Jovanovich, New York, 1977 (2nd ed.).

10. Williamson, K. J., and Hudspeth, R. T., "Teaching Holisitc Thought Through Engineering Design," Engineering Education, Vol. 72, No. 7, April 1982, pp. 698-703.

11. Florman, S. C., The Existential Pleasures of Engineering, St. Martins Press, New york, 1976.

12. Freedman, J. L., Carlsmith, J. M., and Sears, D. O., Social Psychology, Prentice-Hall, Englewood Cliffs, New Jersey, 1970.

13. Schmuck, R. A., and Schmuck, P. A., Group Processes in the Classroom, Wm. C. Brown Publ., Dubuque, Iowa, 1979.

14. Cartwright, D., and Zander, A., (eds.), Group Dynamics, Research and Theory, Harper & Row, New York, 1968.

15. DuBois, N. F., Alverson, G. F., and Staley, R. K., Educational Psychology and Instructional Decisions, Dorsey Press, Homewood, Illinois, 1979 (3rd ed.).

16. Kolb, D. A., Rubin, I. M., and McIntyre, J. M., (eds.), Organizational Psychology, A Book of Readings,

Prentice-Hall, Englewood Cliffs, New Jersey, 1979, (3rd ed.).

17. Kolb, D. A., Rubin, I. M., and McIntyre, J. M., Organizational Psychology, An Experimental Approach, Prentice-Hall, Englewood Cliffs, New Jersey, 1979, (3rd ed.).

18. Homans, G. C., "Group Factors in Worker Productivity," in H. Proshansky and L. Seidenberg (eds.), Basic Studies in Social Psychology, Holt, New york, 1965.

19. Hovland, C. I., and Weiss, W., "The Influence of Course Credibility on Communication Effectiveness," Public Opinion Quarterly, Vol. 15, 1952, pp. 635-650.

20. Aronson, E., Turner, J., and Carlsmith, J. M., "Communication Credibility and Communication Discrepancy," Journal of Abnormal and Social Psychology, Vol. 67, 1963, pp. 31-36.

21. Adams, J. L., Conceptual Blockbusting: A Pleasurable Guide to Better Problem Solving, San Francisco Book Co., San Francisco, 1976.

22. Dusay, J. M., Egograms, Harper & Row, 1977.

23. Jongeward, D., and James, M., Winning with People: Group Exercises in Transactional Analysis, Addison-Wesley, Reading, Massachusetts, 1973.

24. Jongeward, D., and James, M., Born to Win: Transactional Analysis with Gestalt Experiments, Addison-Wesley, Reading, Massachusetts, 1971.

25. Osborn, A., Applied Imagination, Schribner°s, New York, 1953.

26. Woods, D. A., On Teaching Problem-Solving, Dept. of Chemical Engineering, McMaster University, Hamilton, Ontario, 1980.

27. Cordon, W. J. J., Synectics, The Development of Creative Capacity, Harper & Row, New York, 1961. In paperback, Collier-Macmillan, New York, 1968.

28. Karpman, S. B., "Fairy Tales and Script Drama Analysis," Transactional Analysis Bulletin, Vol. 7, No. 6, 1968, pp. 39-43.

29. Berne, E., Transactional Analysis in Psychotherapy, Grove Press, New york, 1961.

30. Perls, F., Hefferline, R., and Goodman, P., Gestalt Therapy: Excitement and Crowth in the Human Per-

sonality, Dell, New York, 1951.

31. Berne, E., Games People Play, Grove Press, New York, 1964.

32. Bass, B., Leadership Psychology and Organizational Behavior, Harper & Brothers, New York, 1960.

33. Forsdale, L., Nonverbal Communication, Harcourt Brace Jovanovich, New York, 1974.

34. Rogers, R. C., and Farsou, R. E., Active Listening, in [16], pp. 168-180.

35. Wales, C. E., and Stager, R. A., Guided Design, West Virginia University, 1976.

36. Vroom, V. H., and Yetton, P., Leadership and Decision Making, University of Pittsburgh Press, Pittsburgh, Pennsylvania, 1973.

37. Vroom, V. H., and Jago, A. C., "Decision Making as a Social Process: Normative and Descriptive Models of Leader Behavior," Decision Sciences, Vol. 5, 1974.

38. Wolfe, D. M., and Kolb, D. A., "Career Development, Personal Growth and Experimental Learning," in [16], pp. 535-563.

39. Plovnick, M. S., "Primary Care Career Choices and Medical Student Learning Styles," Journal of Medical Education, Vol. 50, 1975, pp. 849-855.

40. Hudson, L., Contrary Imaginations, Penguin Books, Middlesex, England, 1966.