

## THE TEACHER'S ROLE IN FOSTERING CREATIVITY

by

Arnold E. Ross\*

Concern with the issue which I am about to discuss goes back to antiquity. We often remind ourselves of this by describing certain desirable pupil-teacher interactions as Socratic dialogue.

The history since then of our practices in bringing up our youth to face responsibilities of citizenship and acquiring the arts of survival is rich in lessons for our generation.

The time set aside for our discussion today barely allows us to begin with the era of Sputnik. At that time we were already a technological society even though a young one. Appearance of Sputnik made us dramatically aware of our shortcomings. In order to enhance the quality of our competitiveness great material resources were thrown at the problem of improvement of our science education. Many of our able university colleagues became deeply involved.

There was a great variety of programs engendered by the opportunities of that exciting era.

Many university and college colleagues became directly involved in pre-college programs of various quality of ambition varying from remedial efforts to energetic attempts to seek out and develop young talent. Not many of these programs have survived.

There were many enhancement programs for teachers. Some of these were limited to summers and some were in place during the whole academic year. Science curriculum content was important in all of them. Courses from schools of education formed an appreciable part of many programs designed for teachers.

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There were massive projects meant to design superior curricula. At first these were meant to be teacher proof. By the time this fatal error was recognized and the projects were broadened to include imaginative teacher education, it was too late to ensure the survival of the programs in the schools for which they were intended. This problem persists to the present day. The very timely and well conceived Curriculum and Evaluation Standards for School Mathematics of the NCTM and the very comprehensive "2060 Science Curriculum" of the AAAS will suffer the same sad fate unless we learn well the lessons of the past.

Among our colleagues who have not forgotten the lessons of the Sputnik era, there is a growing concern that we must make a strong effort to improve the learning environment of our students by providing them with opportunities for active involvement through observation and through that to learning by discovery. However good the textbook and however rich the curriculum, the key to the achievement of these indisputably worthy objectives is the classroom teacher. The depth of the teacher's understanding of the ideas involved and of what constitutes an effective process of learning determine the quality of his influence upon his young charges. Sadly enough the prevailing *ex cathedra* mode of teacher education does not develop the requisite qualities. It seems that introducing the teacher to a deeper understanding of subject matter when combined with an opportunity to observe at very close quarters our own efforts (where no alibis for failure are allowed!) to create a stimulating learning environment, is a desirable and a very stimulating enterprise. It proved to be very successful in the Sputnik era and we have revived it last summer.<sup>1</sup>

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<sup>1</sup> Let me note that the "apprenticeship" component is present, even though not with the same intensity, in the large scale imaginative intervention programs such as Harvey Keynes' program covering the state of Minnesota and in the program of Frank Demana and Bert Waits centered in Ohio. This is true also of Manuel Berriozabal in San Antonio, Texas

We believe that the critically needed reform in pre-college teaching calls for a drastic change in outlook on the part of the teacher. This change involves not only a selection and rearrangement of curriculum topics but a more thoughtful and deeper treatment of these topics challenging the student to observe, conjecture, put his conjectures to the critical test of possible counterexamples, and finally to develop a convincing justification for the surviving conjectures. Such progression of involvement represents a way of life for every scientist and not only for a mathematician. Mathematics, if approached properly, provides an early accessible opportunity for the development of the capacity for scientific thinking in the very young.

The academic component of our program for teachers is designed with the aim of developing the capacity for scientific thinking. The teachers are much moved by the opportunity to observe us at work with the very young<sup>2</sup> in which we challenge our young charges with ideas not usually considered accessible to them.<sup>3</sup> The first teacher's reaction is that of incredulity. This changes into a feeling of deep intellectual excitement and a growing conviction that they should attempt to go beyond rote practice in their own teaching. Observing us at work with students gives them courage to try to do this (cf. Plates I-IVb).

Our teacher participants explore the same range of ideas as do the youngsters in our program. This adds to the value of their observations of our efforts. They have their own problem seminars which parallel those attended by the youngsters. Also, they work in

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<sup>2</sup> These are the participants in our SSTP. Last summer was the 31st year of our program's existence. Descriptive materials can be obtained upon request.

<sup>3</sup> "Report of the Notre Dame Program for Gifted Children," *The Mathematics Teacher*, October 1961, and "Talent Search and Development," *Math Scientist*, 1978, Vol. 3, pp. 1-7.

their mathematics laboratory staffed with very competent assistants for four hours every afternoon.

I do not feel that I can claim a special kind of wisdom in putting together a teacher's program combining rich mathematical experience with the best features of apprenticeship.

Following Sputnik the National Science Foundation made considerable material resources available for teachers' programs. The unhappy events in Europe brought to our shores an incredible constellation of talent and academic wisdom. I was reminded of this when I discovered a report entitled, "To Teach How To Teach How To Do" written in 1962. It was exciting to be reminded that the list of faculty colleagues in the program included Prof. Walter Ledermann, Prof. W. W. Rogosinski, Prof. Thoralf Skolem, Prof. Kurt Mahler, Prof. H. D. Kloosterman, Father Ivo Thomas, Prof. S. Chowla, Prof. Max Beberman, Prof. B. A. Amira (Jerusalem), Prof. R. P. Bambah (India), Prof. Max Dehn, Prof. Ranko Bojanic, Prof. Abraham Goetz (Poland). Among the visitors giving from one to three lectures were Prof. Herbert Vaughan, Prof. Robert Davis, Dean Francis Keppel, Prof. David Page, Honorable John Brademas, Prof. Jorge Carbonell Borbonet (Uruguay), Prof. Richard Guy (Malaya), Prof. Barros Pereira (Brazil), Prof. A. A. Albert, Prof. Alfred Brauer, Prof. Hans Jonas, Prof. Wilhelm Magnus, Prof. E. J. McShane, Prof. Marston Morse, Prof. Paul Rosenbloom, Prof. W. Warwick Sawyer, Prof. John Todd, Prof. Paul Erdos, Prof. Solomon Lefschetz, Prof. Harry Vandiver, Prof. Horst Leptin (Germany).

The youngsters became involved through a happy accident. In the spring of 1957 a number of parents phoned me expressing a concern that their able and active children had nothing worthwhile to do in the coming summer. I fitted these youngsters into the ground level of our (multilevel) teachers' program. The young newcomers performed exceedingly

well. The fact that the ideas forming the heart of the curriculum designed for the teachers was accessible to our very young audience changed profoundly the attitude of the teachers. It helped to overcome the teachers' skepticism about the appropriateness of the curriculum designed for them. This effect could be observed very vividly last summer (1988).

Our teacher program has always been multilevel. This appeared to be desirable for youngsters as well. The point of departure seemed to be appropriate for both groups. It was far from obvious just how large the intersection of the two programs should be.

A great deal of soul searching took place in 1960± as we were trying to decide upon the curriculum.<sup>4</sup>

We found that whenever the selection of participants uses some measure of their potential, inasmuch as it can be judged through the quality of their initiative, intensity of their preoccupation, and the degree of their perseverance, one is bound to net a group representing a wide spectrum of interest and temperament.

At the outset, therefore, we are confronted with the dilemma as to what purpose should be served by a program for a collection of young individuals who have in common only eagerness, curiosity, an unbounded (and hitherto undirected) supply of vitality and, possibly, an ultimate destiny in science.

Even at that time mathematics and science began to permeate the work of most of the professions and were becoming a vital part of our increasingly sophisticated technological society. It became important to respond to this change in environment. Nevertheless, in doing this we had to take into account that our charges were too young to be sure of the choice of a career. Therefore, we had to make an effort to open for them as

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<sup>4</sup> "Report of the Notre Dame Program for Gifted Children," *The Mathematics Teacher*, October 1961, and "Talent Search and Development," *Math Scientist*, 1978, Vol. 3, pp. 1-7.

many doors into the future as possible and guard against creating an undue influence which would narrow their outlook.

We have settled on the objective of providing a vivid apprenticeship to a life of exploration. We are governed by the knowledge that science floats on a sea of mathematics. Therefore, the basis of our program is intensely mathematical. We have felt that the education of future explorers should encourage the kind of involvement which developed the capacity to observe keenly, to ask astute questions, and to recognize significant problems. This is important for two reasons. First, the progress of every science depends upon the capacity of its practitioners to ask penetrating questions and to identify important problems. Second, we believe that personal discovery is a vital part of the learning process for every individual eager to gain deep insight into his subject.

Since 1957, we have used Number Theory as the basic vehicle for the development of the students' capacity for observation, invention, the use of language, and all those traits of character which constitute intellectual discipline. We have chosen Number Theory because of its wealth of accessible, yet fundamental and deep, mathematical ideas and for its wealth of challenging but tractable problems. In our treatment of Number Theory we make use of the fact that it has been the birthplace of modern abstract algebra and provides the underpinning of the study of combinatorics and of discrete mathematics generally as well as an introduction to many ideas of modern abstract mathematics and to the theoretical tools of sophisticated contemporary technology.

Naturally, Number Theory presents one with an embarrassment of riches. However, in selecting (out of a great multitude of possibilities) ideas and methods for our studies in Number Theory, we have chosen those ideas which have had the greatest impact in mathematics, both pure and applied.

Problem solving serves as the means of achieving deep student involvement. We take advantage of the fact that problems may serve not only as exercises in the use of acquired techniques and in the development of heuristic skills but they can and should also be used as a device which helps to achieve deeper understanding of new ideas. Our use of problems in this last manner was noted by Arthur Engel.<sup>5</sup>

Students do from twelve to twenty problems a day. Subheadings in the daily problem sets emphasize our efforts to point up the cultural content of the experience of exploration. Let me mention a few of these: "To think deeply on simple things," "Prove or disprove and salvage if possible" (Never 'Prove' Alone!), "Numerical Problems - Some Food for Thought," "Technique of Generalization," "Exploration," etc.

Our program is multilevel. One would find a more complete description of what we do in "Talent Search and Development" (*Math Scientist*, 1977) and also in our descriptive application materials available upon request.

Have we succeeded during the thirty-one years of our existence to broaden and deepen our youngsters' outlook rather than delimit it? We may derive some comfort from the fact that of the twenty-eight (28) among our program alumni studying at MIT and Harvard at this time, nine have majors in mathematics, four have majors in physics, three in chemistry, four in biology, five in electrical engineering, two in computer science, and one has a major in economics. Of the eight postgraduate students at Berkeley and Stanford, one is doing mathematics, six (one of whom has a Ph.D in mathematics) are doing physics, one is doing biophysics, and one studies neurology after earning a Ph.D in mathematics.

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<sup>5</sup> Jahrbuch Uberbricke Mathematik, 1979.

A similarly wide distribution of interests is found among the mature alumni already settled in their professions. Of the four alumni on the faculty at Princeton, one is an economist (Sloan, 1986), one is a distinguished logician, one is a well-known geophysicist, and one is a mathematician. A light country-wide scan of program alumni finds a young woman astrophysicist at Harvard-Smithsonian (Rossi High Energy Astronomy Award, 1986), and physicists at Livermore, University of Pennsylvania and Cornell. Among the many accomplished mathematicians and computer scientists, one may mention one McArthur award (Berkeley), one proof of Tate-Shafarevich conjecture (outstanding for 25 years), at least two Young Scientist Presidential Awards, numerous Sloan Fellowships, and among computer scientists, one pioneer in symbolic manipulation by computers (IBM-Scratch Pad). At least six people are concerned with the theoretical economic concerns of business, industry, and the professions at Stanford, University of Illinois, The Ohio State University, AMA, and in Canada. This list can be much expanded. We are at present studying the effect of our program over the period of thirty-one years of its existence, upon about fifteen hundred of our alumni.

Many people ask: How can the observation of the work with very capable and eager youngsters help the teacher to confront the usual student audience in a secondary school classroom? We feel that the vital issues of concern to every teacher can be exhibited more vividly and convincingly in working with a responsive audience. The scope of the content may vary for different student audiences, but the basic principles which assure deep student involvement are universal. This is substantiated by the experience of our current group of teachers.



Our summer program for the youngsters was born in the Sputnik era as an adjunct to our program for teachers. Over a period of years it acquired a life of its own and was kept alive in spite of the paucity of material support.

Our current revival of the teachers' program (which alas did not survive) turns things around. It is organized as an adjunct of our summer program for able youngsters.

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**"... As a teacher, I feel that this program has awakened me from too long a period of dormant complacency. The challenge and intensity of the program has reawakened my interest in continued education and revitalized my enthusiasm for the more difficult math courses. Learning from example can never be overstated and these last weeks have allowed me to see the best at work ... Students are guided to discover non-trivial concepts naturally in a setting geared to experimentation and conjecture. The problem sets are carefully picked so that major ideas are foreshadowed early in the course. The intensity level is designed to challenge the most gifted, but still keep all working without discouragement. We are pushed to achieve at a higher level than thought possible and only in retrospect can one fully appreciate the vast strides made in understanding the subject matter.**

**This program is of extreme benefit for teachers because it works with a segment of the high school population that is essential for the success of this nation and that is all too often neglected, the very able student.**

**This summer has been the most significant educational experience that I have had for many years. If the basic premise that the future of this country is in the hands of our gifted young population and that a better teacher will help produce a better student, then programs such as this must be allowed to flourish throughout our country. I, personally, will carry the fruits of this summer's labor with me for many years."**

**Pat Mauch  
Ekalaka, Montana**

**(Plate I)**

**"... Oftentimes a colleague could draw from his experience and share it with the rest of us and that would set us off exploring a topic even further. In our every day teaching, moments like that are few and far between, being caught up in the whirlwind of activity that is common to us all. It was refreshing and stimulating to be in an atmosphere of discovery. I am challenged to give to my students the same spirit of discovery which I observed and was part of this past summer. It is not an easy task and it is not always as successful as we would like it to be, but it is imperative that we 'give it our best shot.'"**

**Val Stevens  
Genoa, Ohio**

**(Plate II)**

**"... For the first ten days of this program, I was very skeptical and convinced this program worked only on paper and in the minds of those running this summer session. The more I see of it, the more impressed I have become. The technical aspect of teaching and the pedagogy that translates into effective teaching is, many times, not easily recognized. After many weeks of watching, listening and participating, I can now see how fruitful this program and [its] methods are.**

**I have taught mathematics in the public high schools for 24 years. I have observed, slept, dreamt, debated, laughed, cried and loved teaching. There are many things in the teaching profession that are hard to change. Teachers are sometimes slow to change, hard to convince and slow to accept innovations in the art of teaching. They must be persuaded to accept new ideas and tech-niques and to try them.**

**[Observing the young participants] I have noticed an awakening of many of these kids. They have learned to be more investigative and eager for knowledge. These young students search for patterns, make conjectures and study long and hard. They are learning to formulate and present good questions and to discover many new mathematical concepts.**

**I have been convinced it works...**

**This has been one of the best and most intense learning experiences of my life."**

**Larry D. Kight  
Beardstown, Illinois**

**(Plate III)**

**"Immersed in mathematics!"** During the first few days, somehow that phrase seemed an inappropriate description of the summer mathematics institute. A more striking comparison would be to dump a non-swimmer in the deepest part of the blood-thirsty, shark-infested Atlantic Ocean and yelling to the victim, "Swim." New concepts of number theory were constantly being hurled at the struggling in hopes that an element would be used as a rescue line to stay afloat. Unknowingly the situation rapidly surfaced into a learning experience with the freedom to delve [into] and investigate the many facets of mathematics that most science teachers never question. As the experience at the institute progressed, a tremendous number of phase changes occurred as "liquid" fundamental concepts began to "gel" and later developed into the building blocks for a "concrete" foundation for an even further expanded investigation. As the new school year proceeds and questioning through the "discovery" method is more fully expanded, this "skeptic" will be prepared to meet and accept the "test" of another challenge at the 1989 institute.

**Philip Jones  
"The Skeptic"  
Davie, Florida**

**(Plate IVb)**

**"... [Your program] believes equally important to the motivation of the student is the motivation of the teacher, and more important than motivation of the science and mathematics teacher to pedagogical method is his motivation to the spirit of the scientific method."**

**Pauline King Long  
Birmingham, Alabama**

**(Plate V)**