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CREATIVITY, ETHICS AND SPECIALIZATION IN ENGINEERING

(First draft was titled: "The Pseudo-Spiral of Creative Thought.")

* A series of manuscripts on the social relations of engineering and related philosophical questions dealing with the interaction of science and society. Distribution is limited to reviewers and discussion groups for criticism prior to consideration for possible publication.

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11/20/61	G	Diagrams only.
9/9/62	I	Text
11/19/62	I	Revised
2/27/64	J	Updated
4/24/64	K	Revised
1/3/70	L	Updated

Creativity, Ethics and Specialization in Engineering

Introduction

A series of working paper drafts have been produced as a byproduct of my engineering work as Socio-Engineering Problems Reports. The purpose of this paper is to inquire of the process by which these thoughts are developed and what their relationship is to the technical engineering problems. For reference a short list of some of these reports are listed in Table I.*

The Pseudo-Spiral of Creative Thought.

Professor Sarton gives a figure showing two alternative paths by which mathematical concepts might be developed.(1) He shows a roughly straight line path A to B in the left of Fig. 1. On the right of the same figure, he shows a pseudo-spiral curve which loops and winds around and eventually gets to the end point B. To quote Professor Sarton:

> "We need equally the two kinds of syntheses: the historical and the purely mathematical. The latter is the shortest if not always the easiest path to knowledge, but it fails to explain the human implications; it may satisfy the matter-of-fact and hurried mathematician; it cannot satisfy the philosopher and humanist.
>
> "As to the pure mathematician, even he should not be too easily satisfied with the latest synthesis, to begin with, that synthesis may be incomplete. Some elements which were not deemed essential for it may have other values, they may prove to be essential for other structures, or the one from which they were eliminated may not be as final as it seems.

(1) George Sarton, The Study of the History of Mathematics. N.Y.: Dover(1957), p. 20. Reprint of 1936 book of the same title plus "The Study of the History of Science."

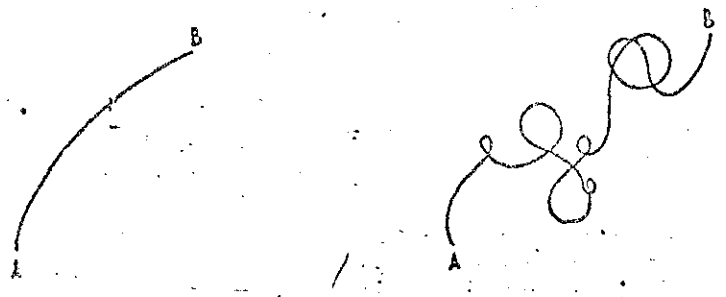

Fig. 1. Alternate Paths Between Two Mathematical Discoveries (from Sarton).

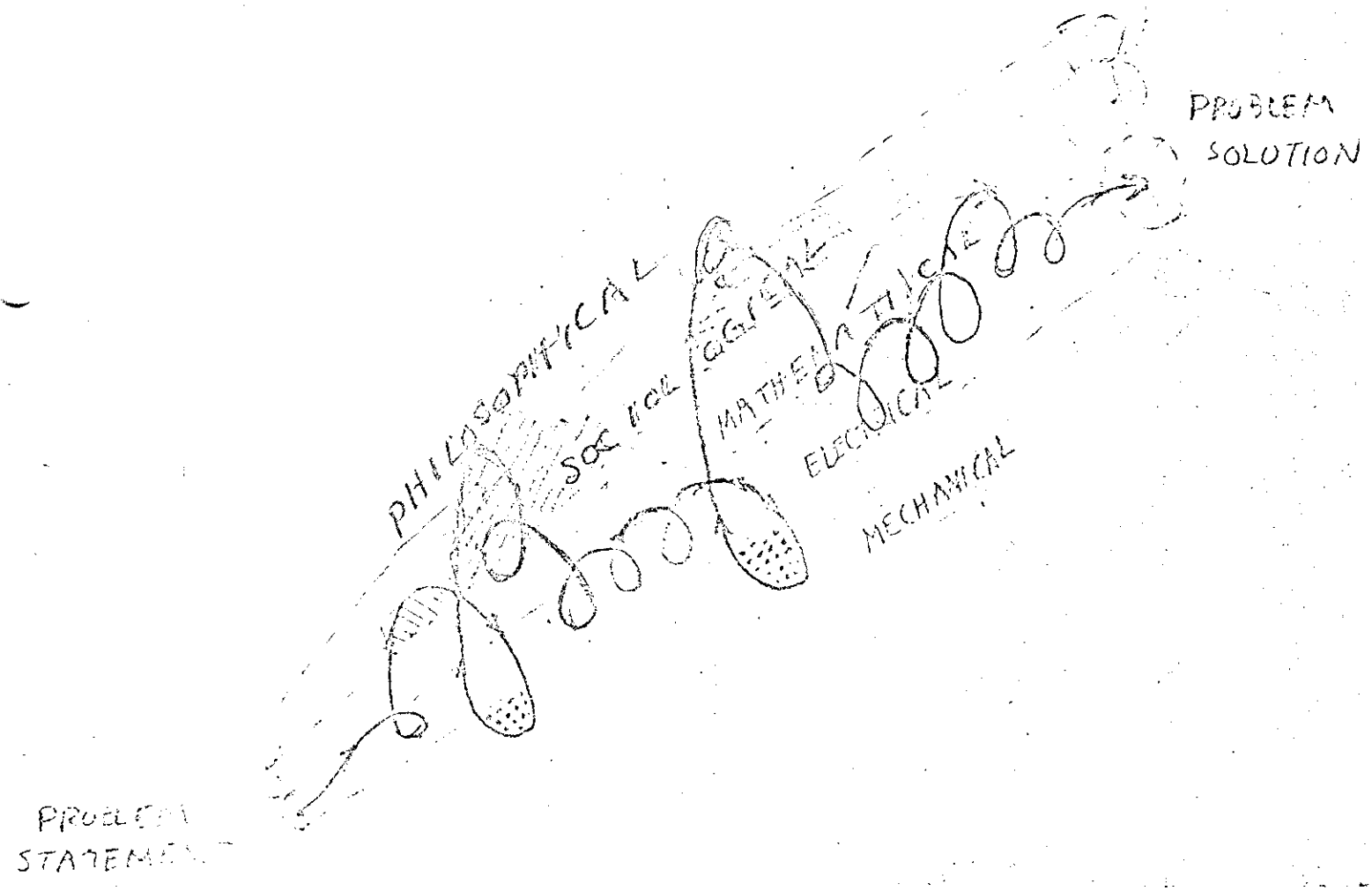

Fig. 2A. An Example of a Pseudo-Spiral of Creative Thought in the Analysis and Design of a Computer-Communication System.

> Indeed, no theory is ever final. A new discovery, a new point of view may cause its abandonment and its supercedure by another, and the facts neglected in one shuffling may be considered invaluable in another. Every synthesis implies sacrifices; it is not merely a simplification but also unavoidably a betrayal of reality, a distortion of the truth, and the mathematician who takes the trouble of considering the origin and evolution of ideas, as well as the final shape, will improve his understanding of them and enrich his mind." (2)

My reading of Professor Sarton's book reminded me that in my engineering work the periods of greatest progress have usually been times when I have followed a pseudo-spiral path similar to professor Sarton's second curve in Fig. 1. In my own case I am able to add a rough definition of the space cross-section in electrical, mechanical, mathematical, sociological and philosophical sectors as is shown in Fig. 2.

This spiral path in Fig. 2 illustrates the way my thoughts proceed in the investigation of an electrical engineering problem. The consideration of the problem statement for the electrical case may lead to a mathematical formulation, which has a potential interpretation in terms of sociological phenomena, and in some cases leads to a philosophical abstraction which in turn leads back to a clearer conception of the different parts of the electrical circuit problem.

It has been my experience that when the natural paths that occur in my thought processes are followed, an excursion through

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2. Ibid., p. 21

sociological analogies always leads back to the testing of mathematical theorems and onto the desired electrical problems. I find that attempts to cut off or break the spirals through related phenomena in thought, stop the creative thought process short. This appears to relate to a basic philosophical idea inherent in our Hebrew-Christian tradition upon which Western Civilization is based, namely the concept of "wholeness," or "integrated personality."

Compartmentalization and Channel Capacity.

I am aware that many people develop a compartmentalization so that they can reject any ethical implications in their work. I feel that is important to explore this to determine what aspects of this phenomenon are important to the functioning and preservation of our civilization. This concept of "logic-tight compartments", i.e., people specializing in one field and not paying attention to the relationship to the rest of society, has been under attack for a long time by religious leaders. For example, Ligon in his 1937 book on the theory of Christian personality (3) deplored the extent to which people in the business world and the academic world isolated their Sunday religious ethics from contact with their daily work.

3. Ernest M. Ligon, The Psychology of Christian Personality. N.Y.: The Macmillan Co.(1937), pp. 144-151. Some of the concepts in this 1937 book on psychology are outdated in the light of the last twenty-five years of psychological research. However these particular comments on oaths and logic-tight compartments remain quite valid. Furthermore there are physiological reasons for avoiding overspecialization (See ref. 5.).

At earlier stages in the development of science, the logic-tight compartments may have been necessary to (1) protect scientists from political controversy, and (2) help scientists keep the information they are trying to handle within their "channel capacity." In psychiatry the phenomena of exceeding one's "channel capacity" is more commonly referred to as "information input overload," as was done by Dr. James G. Miller in his 1960 article on the subject.(4)

4. James G. Miller, "Information Input Overload in Psychopathology." Amer Journal of Psychiatry, Feb. 1960

In addition to there being sociological and religious grounds for avoiding over-specialization, there are physiological reasons, indicated by the following quotation from Dr. N. E. Ischlondsky:

"The Danger of Specialization" (5)

A person aiming at specialization in the professions particularly needs a varied background of education for physiological reasons, quite apart from the humanities. ...Dr. N. E. Ischlondsky, Paris and New York specialist in brain physiology, told a meeting of the Commonwealth Club in San Francisco:

> "Only a broad general education will provide the future specialist with the wide net of brain connections indispensable to integrative thought."

Dr. Ischlondsky postulates that there are ample physiological reasons for steering clear of narrow specialization:

> "If the brain of a growing individual is being develped one-sidedly, this may lead to such an intense stimulation of a very restricted portion of the cerebral cortex, the seat of finer psychic reactions and discriminations that induction emanating from it may greatly inhibit the rest of the brain.
>
> "There results not merely a lack of development of the affected areas, but also a decline in their notmal functioning capacity, " Dr. Ischlondsky added.

5. Mental Health Progress, Dept. of Mental Hygiene, Sacramento, Calif., Vol. 13, No. 9, page 9, November 1962.

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The Gap Between The Two Cultures.

To return to the sociological concept of C. P. Snow's "gap between the two cultures" of the sciences and the humanities, we see that the pseudo-spiral of creative thought automatically cuts across the gap or at least segments of it. An engineer or scientist left to his own natural inclinations, provided the educational system had not already crippled large part of his creative ability, would automatically do his part in bridging the gap. This automatic process is dependent upon the engineer or scientist "becoming a person" in the sense used by Carl Rogers.(*)

* Carl R. Rogers, On Becoming A Person. Boston: Houghton Mifflin Co. (1961). esp. Chap. 21: The Place of the Individual in the New World of the Behavioral Sciences.

C. P. Snow's later public lectures contained some important points not included in his more widely circulated papers.(6)

6. Unpublished comments by C.P. Snow in Physics Department seminar, University of California, Berkeley(1960).
C. P. Snow pointed out that our civilization has learned how to organize lesser qualified scientists and engineers on large projects to accomplish great tasks without relying upon great individual scientists of the stature of Einstein, Fermi, von Neumann, or Oppenheimer.

There are other views in addition to C. P. Snow's regarding the "gap" between the sciences and the humanities. Drucker (7) places the gap between the different specialities of science rather than between the Humanities and the Sciences. Vannevar Bush (8) places this gap more in the development of the individuals than in a difference of areas of knowledge.

7. Peter Drucker, "New Knowledge in PHYSICS and the ECONOMY," Physics Today, July 1962, pp. 36-46.

8. Vannevar Bush. "Two Cultures," Technology Review, Nov 1962, pp. 21-22.

The late Norbert Wiener at a symposium at Purdue in April 1961 made the following remarks as part of a discussion "On The Function of Science in Society": (§)

> "What I have said has a definite relevance to the training of scientists. We want people who will be able to face yet unknown situations, by as yet unknown combinations of ideas from different fields of work. For this, a broad basic training is necessary. So, too, are crossing the boundaries of scientific specailization, interdisciplinary thinking, and a willingness to take all that one has acquired as part of one's available assets. On this side of the Iron Curtain a present difficulty is the tendency to parcel out science in small pieces, to divide scientists into two classes. The independent people are being given the information, but are mostly doing administration; thus, they are not thinking about the priblems. On the other hand, the "stooges" are given a particular piece of a piece of a problem to do. They have neither the training required nor access to information about related pieces of the problem and therefore cannot do efficient work.
>
> I believe that it is extremely important to have a broad basis in very different sciences for one's intellectual work so that one can follow the problem wherever it leads, even though it crosses boundaries. There should not be a customhouse between one science and another where one must pay duty when going from, say, physics to chemistry, chemistry to biology, or mathematics to realism. We must keep for ourselves and for our students an attitude that a wide interest in intellectual matters is desirable and necessary. If a problem leads us into a new field in which we have no knowledge, we should acquire such knowledge. It is now excuse, when working on a problem, to say "but that's not my field." At some stage or other one must decide to learn what is needed about the field; those who do not are "stooges" who are not serving their social function for science."

§ Norbert Wiener, "The Mathematics of Self-Organizing Systems," pp. 1-21, Appendix III: On The Function Of Science In Society, pp. 18-21, in Robert E. Machol and Paul Gray, Recent Developments in Information and Decision Processes. N.Y.: The Macmillan Co. (1962)

There is another paper by Norbert Wiener, which I can't find at present, which includes some discussion of the time in years it takes for a scientist to develop the techniques and acquire the knowledge to attack the major problems of our civilization. If I remember correctly, he estimates it takes ten to twenty years to acquire the preparation for some problems, yet the structure of both academic and industrial science organization in the U.S.A. is geared to much shorter periods of obtaining results. (&)

Sample Time Distribution

If we examine Fig. 2 to determine the average fraction of time in the different domains such as philosophical, sociological, mathematical, electrical, and mechanical, we obtain a distribution as follows: 49% electrical, 23% mathematical, and 9% mechanical; adding up to 81% engineering and 19% for sociological and philosophical. These relative time distributions are plotted in Fig. 3. If one is actively working in an integrated way five days a week plus studying and working on reports three evenings plus Saturday mornings, the total hours per week comes to about 56 hours. A time scale based on this estimate is included on the right in Fig. 3 for reference.

Replot of Time Distribution On Checking Chart.

& Some further comments of N. Wiener can be found in Martin Greenberger, Management and the Computer of the Future. Boston:M.I.T. Press(1962)

It is instructive to replot the thought processing stream and the subject classification in another coordinate system known as a "checking chart." Since the form of checking chart in the 1959 WJCC paper had its coordinates removed in editing(#) I shall refer back to the original source of the checking chart.

F. B. Wood, Proc. 1959 WJCC, pp. 310-313. or SEP No. 27-A or SSPS #5

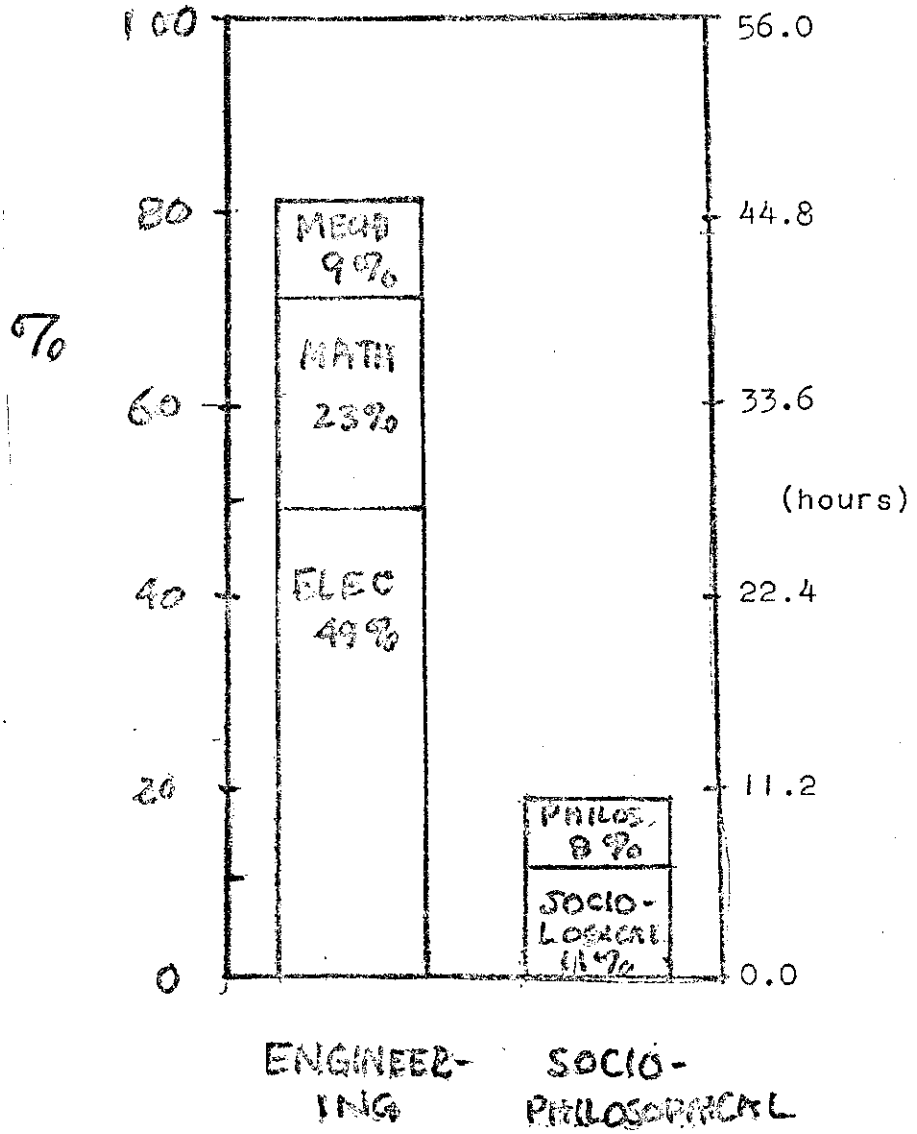

Fig 3. Sample Time Distribution (Typical Week in 1959 - 1961 era)