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AN ANALYSIS OF THE TREND TO MAKE A SCIENCE OF EDUCATION

DISSERTATION

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By

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* * * * *

The Ohio State University
1978

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For my Mother and Father
who made this possible.
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INTRODUCTION

We live in an age where everything must be defined, classified, categorized, and, if possible, quantified. Within the structure of the scientific community there exists a pecking order with the natural scientists and mathematicians perched at the top and the social scientists scratching their way along in an attempt to secure a resting place somewhere on the roost. With mathematics holding the laurels as the queen of the sciences, the physicists have always tried to be as mathematical as possible, and since the time of Galileo have been immensely successful in their efforts. Today we see the biologists with their emphasis on the molecular gene structure trying to be as much like chemists and physicists as possible. Not to pass over the psychologists, we find the behaviorists trying to reduce human behavior to a set of physio-chemical explanations. I am reminded of Voltaire's zany monologue in Peter Weiss' play Marat/Sade where Voltaire pokes fun at the ultramechanistic world view of Marat, which is in turn simply an image of eighteenth century continental rationalism:

We have received from a certain Marat
a slim volume entitled Man
This Marat claims in a somewhat revolutionary essay
that the soul exists in the walls of the brain
and from that strategic point controls
the hypodraulic mechanism of the body
by means of a network of tinkling nerve threads
At the same time apparently the soul is receiving messages from the mechanism of the body messages conveyed by pistons plugs and wires which the soul transforms into consciousness through separate centimentrifuges operating as simultaneously in other words it is the opinion of this gentleman that a corn fills the corridors of the brain with pain of the soul and that a troubled soul curdles the liver and kidneys For this kind of ring-a-ring-a-roses we can spare not even our laughter\[1\]

The view persists. All must be reduced to the fundamental laws of nature which ultimately are stateable in the form of mathematical expressions. The further a particular discipline has been reduced to these expressions, the more scientific it becomes.

No field is exempt. It seems today that any pursuit in order to be considered valid and legitimate must attempt to be scientific. Thus, we have the science of business administration, the science of secretarial work, and the science of football. That educators want to be scientists is exemplified by those schools of education which are modeled after medical colleges. (That is easy to understand, though, for after all, it is out of those corridors and laboratories that today's gods come.)

It is the purpose of this paper to trace the scientific movement within education and to make an analysis of that movement. In the first chapter we will show that over the past century there has been

\[1\]Peter Weiss, Marat/Sade (New York: Atheneum, 1972), pp. 67-68.
a definite trend to put education on a scientific basis. In the following chapter we hope to indicate why the trend exists, and to throw light on what the nature of the scientific enterprise is. In the third chapter a detailed description is given of three specific studies in education that purport to be scientific. In the final chapter a critical analysis is made of the three studies described in Chapter III with respect to a list of characteristics that are both basic and common to the scientific endeavor. These characteristics will be arrived at in Chapter II through a historical approach. (See the Appendix for two notes on methodology. One is with regard to the choice of the common characteristics of science and the other is with regard to the selection of the three studies in education.)
CHAPTER I

THE TREND TO MAKE A SCIENCE OF EDUCATION

The trend to make education into a science is not new, but can be traced back at least one hundred years. It is no coincidence that the beginnings of the effort to make a science of education coincide exactly with the beginnings of experimental psychology. Herbart in the first part of the nineteenth century proposed that the interactions of sense perceptions within the mind could be expressed in mathematical formulas like those of Newtonian mechanics, and on such a basis developed a theory of education as a branch of applied psychology. But it was not till the establishment of the first laboratory in experimental psychology by Wilhelm Wundt in Leipzig, Germany, in 1879 that modern psychology can really be said to have begun. It is interesting to note that much of the experimental work done between the time of Herbart and that of Wundt was performed by men who were steeped in the methods of physics, e.g., Thomas Young who wrote a revised and improved theory of color vision based on Newton's work and Hermann von Helmholtz who did experimental work in several areas of psychophysics and physio-psychology including a study of conduction rates in nerves.
Although, as Claparede\textsuperscript{1} points out, the early work in child psychology and experimental pedagogy was the result of work contributed by men and women in various countries, we will concentrate on the work done in the United States. One of the first Americans to apply the findings of experimental psychology to education was Stanley Hall who had earned Harvard's first doctorate in psychology (1878) and then had gone to Germany where he studied with Helmholtz and Wundt. Upon returning to the States he established a laboratory to study the child at Johns Hopkins (1882), and later, when he accepted the presidency of Clark University (1889), he made that university a center for educational psychology and the study of the child. Hall, like most scientists of the time, had been greatly influenced by Darwin's theory of evolution, and was convinced that the mind had evolved throughout geological time just as the body had. This view served not only as an intellectual pivot for his psychology, but also influenced his social views. For example, he believed the curriculum of the school should be based on the natural stages of development that the child goes through as he or she recapitulates the historical evolution of the species. And he was also convinced that heredity played a much more important role in one's intellectual development than did the environment. According to Curti, Hall's belief in social Darwinism even carried him to the limit that,

\textsuperscript{1}Eduard Claparede, \textit{Experimental Pedagogy and the Psychology of the Child} (London: Edward Arnold, 1913), Chap. 1.
"Sterilization and segregation of the unfit were eminently practical measures."² Here is an example of the danger of extrapolating a scientific theory into a region for which it was never intended. Darwin's theory deals with the evolution of biological species over geological time, not with the development of individual man over a segment of human history.

By the end of the nineteenth century Edward Thorndike's experimental work with animals had led him to propose his well-known theory of learning based on the stimulus-response connection within the nervous system. This theory led him to believe that the entire field of education could be grounded on the laws and relationships being discovered in psychology. His work with Woodworth on transfer of learning further enhanced his reputation within the young field of educational psychology. This work shattered the common idea prevalent in schools that the training of one's mind that occurs when the child studies, say arithmetic, will carry over and be useful when the child begins his study of a modern language. A practical result of this work was that it hastened the demise of the classics in the schools and fostered the introduction of more utilitarian subjects such as manual arts and natural science. Unfortunately, Thorndike, like Hall, bought into the ideas of social Darwinism and not only believed that native intelligence is a more important factor in

determining the social progress of an individual than is training and environment, but even believed that a measure of high intelligence was in general correlated with a measure of superior character. (See Curti's chapter on Thorndike.)

When John Dewey came to the University of Chicago in 1894 to head the departments of philosophy, psychology, and pedagogy he brought with him not only the ideas of Hegel and Darwin that had influenced him in philosophy, and William James whose Principles of Psychology he had recently read, and Hall's child studies which he had become familiar with as a graduate student at Johns Hopkins, but he also brought his own unique mind which was peaking in its intellectual and creative powers. He was in the process of synthesizing all of his earlier influences and ideas into a mature system of thought that was to establish him as the foremost educator of his century. As early as 1885 Dewey was making statements such as, "The tendency to apply the exact methods of science to problems in education, is one of the most hopeful signs of present pedagogy."³ At Chicago he established the Laboratory School which was to serve the educator in the same manner that a chemistry laboratory serves the chemist. Within the laboratory Dewey could not only test his educational theories, but also observe and experiment in order to arrive at new ideas and theories.

...the school will be a laboratory in which the student of education sees theories and ideas

demonstrated, tested, criticized, enforced, and the evolution of new truths....Such a school is a laboratory of applied psychology....Its task is the problem of viewing the education of the child in the light of the principles of mental activity and processes of growth made known by modern psychology.4

The philosophy and the psychological and educational ideas of Dewey all became interwoven in the curriculum of the school and to this day it has served as the prototype of what good experimental pedagogy consists. Dewey's views that the curriculum should be focused on the immediate needs and interests of the child, that the occupations of the children at school should reflect the life of the larger society so that the child is kept in touch with reality, and that the school provide a common set of experiences, purposes, and values which foster a democratic society were all central to the everyday philosophy of the school.

Dewey believed that education was in a transition from an empirical to a scientific status, and his application of sound psychological findings to the education of children were grounded in this belief. Dewey knew, though, that the application of scientific research to the problems of education were of a very recent origin, and that such applications should proceed with caution due to the complex nature of any educational problem.

No conclusion from scientific research can be converted into an immediate rule of educational art. For there is no educational practice whatever

which is not highly complex; that is to say, which does not contain many other conditions and factors that are included in the scientific finding.\(^5\)

Dewey would be very leery of those fact-hunters who apply their specific statistical studies to areas such as school administration or instruction. There are so many variables in the educational process that the results of any specific study should only be used with precaution. As an example there has been a strong and concerted effort in this country ever since the beginning of this century to increase the efficiency of our schools by utilizing the technique of scientific management. If one looks at this movement in detail as Callahan has, one finds that all it amounts to is the application of business accounting techniques, industrial efficiency studies, and statistical samplings to problems within the school. It is grounded in the belief that education is a business, and has resulted in two generations of administrators who fail to see that educational administration is much more than business-industrial management. If educational administration is to be grounded on any firm basis it must be on the formulations provided by philosophy and the social sciences. By failing to take into account the social and philosophical conditions which contribute to the complexity of any educational problem, and only concerning themselves with the application of big-business techniques, the efficiency experts were guilty of the very thing that Dewey warned against.

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One must also be very careful how the term scientific research is used. Note that the efficiency experts used the work scientific to label a technique that was little more than a system of accounting. As we shall see the collection of data resulting in statistical analysis does not constitute a science. According to Callahan, "Partly for the purpose of defense and partly for the purposes of gaining status the leaders in administration claimed the label "scientific" for their accounting procedures." Dewey, too, was familiar with the status symbol attached to the word science:

...science is of value because it puts a stamp of final approval upon this and that specific procedure....It is prized for its prestige rather than as an organ of personal illumination and liberation. It is prized because it is thought to give unquestionable authenticity and authority to a specific procedure to be carried out in the school room.

Later on in the same little book Dewey makes this acute observation:

The shortest cut to get something that looks scientific is to make a statistical study of existing practices and desires, with the supposition that their accurate determination will settle the subject-matter to be taught, thus taking curriculum-forming out of the air, putting it on a solid factual basis.

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7 Dewey, op. cit., p. 15.

8 Ibid., pp. 72-73.
Fifty years later and we still hear from those who think of education as a business. In an article in the October 1958 issue of *Fortune* the writer talks about how productivity is declining in education, "we would want the schools to turn out students with the greatest possible efficiency, i.e., we would want to optimize the number of students, and we would want to minimize the input of man-hours and capital." No mention is made of the quality of education, nor is mention made of Mark Hopkins. In the article Selligman refers to scientific programming which is simply an attempt to cut costs by such means as the more efficient use of scheduling courses and cutting down on travel time between classes. Here, again, is another example of the misuse of the word scientific, as it is being used only in the sense in which Callahan and Dewey spoke of it above, "for the purpose of gaining status." In the last section of the article he makes the statement, "The schools have just begun to discover scientific management," as though this had not been the whole thrust of the efficiency cult since 1910!

Fortunately, the research in education has not been limited to the efficiency experts. There has been a lot of hard, honest work done by investigators who are vitally concerned about the quality of education and who apply to the problems of education the best methods they can borrow from sociology, physiology, economics, psychology,

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10 Ibid., p. 196.
and mathematics. The variables are many, the studies innumerable, the data complex, but the faith of the researchers in the belief that there can be a science of education has been persistent. One has only to look at The Thirty-Seventh Yearbook (Part II) of the National Society for the Study of Education to realize the extent and the devotion to the scientific movement in education.

Out of this mass of materials, now almost unintelligible, they will ultimately bring order and system. And when comparable facts are so ordered and systemized that all unprejudiced observers must travel the same road to the same conclusion, we shall have enlarged still further the bounds of the science of education at the expense of tradition and personal opinion. 11

The movement gathers force, it is not abating. If you went into a school today, you might think that the setting pretty well resembles that of fifty years ago. The pupils sit in their rows and listen to the teacher, and there is still even the school bell, though now it is electric, automatic, and synchronized. But the movement has had its effect. It is there in the new offices of the guidance counselor, the school nutritionist, the media expert, even the sanitary engineer. It is there in the accumulative record file in the form of the IQ, the standardized test scores, the yearly grades, and the social and economic background for each student. It is there in the guise of the psychology that is built into the physical education program, that is written between the pages of the teacher's guides and the student's textbooks, and that is most overtly

11Russell, NEA Proceedings, 1926.
obvious in the form of the school psychologist himself. It is there in the form of teaching techniques, learning aids, and all the more obvious products of technology such as projectors, computer terminals, and mass copiers that are found in our schools today.

We also find the movement prominently displayed throughout our colleges of education. One only has to glance at a list of dissertation titles or the topics of articles in the professional journals to realize how deeply entrenched the scientific movement is in education.

Here was no dabbling with the tricks of the trade that had been the earmarks of the normal school; here was Wissenschaft with a vengeance. Little wonder that professors of education, ever under attack for having no real content to teach, saw in science the great panacea for their field.12

We have theories of instruction, learning, curriculum (the other day I heard mention a theory of evaluation, so I am sure there must be a theory of discipline), and even the field of administration prefers a scientific approach to their problems. The historians prefer the term historiographers and the philosophers call themselves language analysts. Certainly the end for any graduate student is to do a bit of quantitative research, collect his data and construct his tables and graphs, and, if his work is acceptable, see his results published in one of the many professional, research journals. This constitutes his rite of passage.

Only the poets and plumbers remain aloof, the eternal sages. They alone seem to know that a greater truth lies somewhere beyond

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the laws of science, transcendent to the realm of science.

The movement, of course, is not unique to education; in fact the trend that we have traced in education is only a reflection of a general movement throughout our culture. Many areas in our modern society are characterized by this compulsion to be scientific, to devise techniques, to collect, quantify, measure, standardize, categorize. Most areas in the social studies have already capitulated to the methods of the natural sciences and, in fact, are collectively known as the social sciences. The rise of behaviorism within psychology and its attempt to reduce the explanation of human behavior ultimately to the laws of physics and chemistry is but one example of the trend. Everyday we read of a new advance in the medical sciences that range from home-disposable pregnancy tests to techniques as to how to cope with death. Research in the medical sciences is as basic as the gene structure of cancer cells and as applied as engineering techniques in surgery. It goes without saying that the technology resulting from research in the physical sciences is having a greater and greater influence on our lives. The space race and the arms race are only two manifestations of this influence. As Jacques Ellul puts it, "The technical phenomenon is the main preoccupation of our time; in every field men seek to find the most efficient method."\textsuperscript{13} For Ellul it is this very search for greater efficiency that characterizes a given technical action.

Ellul believes that technology is taking over our entire civilization in a completely autonomous manner in the sense that one technique fosters another technique and we are caught in the midst of a geometrical progression of techniques. For Ellul technology means not only the hardware such as machines that are the byproducts of applications in the natural sciences, but also the more subtle techniques resulting from the social sciences. We live in an age of technique. Science itself is technique.

This science extends to greatly diverse areas; it ranges from the act of shaving to the act of organizing the landing in Normandy, or to cremating thousands of departees. Today no human activity escapes this technical imperative. There is technique of organization, as there is a technique of friendship and a technique of swimming.\textsuperscript{14}

Though most of us applaud this rise of technology which has done so much to make our lives comfortable, Ellul takes a very pessimistic attitude towards it.

Technique has penetrated the deepest recesses of the human being. The machine tends not only to create a new human environment, but also to modify man's very essence. The milieu in which he lives is no longer his. He must adapt himself, as though the world were new, to a universe for which he was not created. He was made to go six kilometers an hour, and he goes a thousand. He was made to eat when he was hungry and to sleep when he was sleepy; instead, he obeys a clock. He was made to have contact with living things, and he lives in a world of stone. He was created with a

\textsuperscript{14} Ibid., pp. 21-22.
certain essential unity, and he is fragmented by all
the forces of the modern world.15

To escape from his tormented world man turns to art, entertainment,
and athletics but finds that they, too, are technique. The social
scientists rush to man's aid but only force him deeper into the
technological rut.

They want to restore man's lost unity, and patch
together that which technical advances have
separated. But only one way to accomplish this
ever occurs to them, and that is to use technical
means....
Man is caught like a fly in a bottle. His attempts
at culture, freedom, and creative endeavor have
become mere entries in technique's filing cabinet.16

Ellul's view represents one of the very few dissenting voices
raised against this leviathan of modern technology. Though it sounds
like a prophecy of doom, there is a message to be learned here. Cer-
tainly a tension is needed between the technology of modern society
and the customs and values of our traditional culture. It is in this
tension that man must live and find his meaning.

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15Ibid., p. 325.

16Ibid., pp. 411, 418.
CHAPTER II

CHARACTERISTICS OF THE SCIENTIFIC ENDEAVOR

There is no simple answer as to why there is so much emphasis on bringing everything under the auspices of science. Certainly one reason is the tremendous success the sciences have had over the past four hundred years. They have been successful on two accounts. In the first place they have provided answers to basic philosophical questions that can be traced back to the pre-Socratics such as: What is matter? What is the structure of the universe? Why do things in the natural world work the way they do? It is not surprising that up until this century science was called natural philosophy. The tradition of the ancient Greeks to incorporate a rational explanation of nature into their general philosophy is still one of the most important aspects of modern science. We seek to understand, and we seek to understand because that is part of being human. As Poincare puts it:

The scientist does not study nature because it is useful; he studies it because he delights in it, and he delights in it because it is beautiful. If nature were not beautiful, it would not be worth knowing, and if nature were not worth knowing, life would not be worth living....intellectual beauty is sufficient unto itself, and it is for its own sake,
more perhaps than for the future good of humanity, that the scientist devotes himself to long and difficult labors.¹

The other side to the success story of science is quite remarkable. It turns out that the explanations advanced by the scientist in attempting to answer his philosophical speculations have utilitarian value. That is to say that the answers to the pure questions that he poses can be applied to practical considerations. I don't know why that is the case, but it is. Consider this example. Back in the 1930s a young German whose name was Hans Bethe asked himself what undoubtedly was an ancient question: Why does the sun shine? Notice the childlike innocence of this question. It is posed in the sense of the above quote by Poincare. By much study and thought he arrived at an answer. Story has it that a few days later he was strolling through a park one evening with a lovely young lady. He looked up at the night sky and asked, "Do you realize that I am the only person in the world that knows what makes the stars shine?"

The girl looked at him in complete bewilderment. She wanted a lover, not a thinker. The islands of scholarship are lonely, and so were the islands in the Pacific where fifteen years later the first hydrogen bomb was detonated, the direct application of Bethe's theoretical work.

The goal of science is not only to explain, but to predict and control. It has brought us, through technology (which is the large-

scale application of the laws of science to practical problems), the materially comfortable world in which we live. It has, for example, shown us how to predict, control, and utilize the energy stored in matter. If science, along with its bridesmaid technology, has been responsible for the exponential growth of our modern physical culture, then should not the same methods be brought to bear on all areas of human concern such as sociology, history, and education? It is because of the tremendous success of the natural sciences, both in their pure and applied aspects, that all other pursuits of knowledge wish to become scientific.

Also technology has become the great equalizer. As Mumford puts it:

Mass production, by its very nature, tended to equalize consumption. Was not machine-made jewelry (brummagem) cheap enough for the poor to buy one of the earliest products of Birmingham? That fact was symbolic. Whatever the politics of a country, the machine was a communist. As a result capitalism, which had rested on the Old World principle of class differentiation, was finally, as a measure of self-preservation, forced to accept the "welfare state," with its far-reaching provisions for equalization.2

But, are the methods of the natural sciences applicable to the study of man? To answer this we must ask ourselves what are the methods and characteristics of the natural sciences, and to answer this I have chosen to go back four hundred years and look at the work of those men who initiated the methods of modern science. There we should be able to find those characteristics that define a science,

and we will later use these characteristics in analyzing some areas in education that purport to be scientific.

Until recent scholarship within this century, most historians thought of the revolution that occurred in scientific thought during the sixteenth and seventeenth centuries as an interlude in the more vast and general movement in western intellectual thought known as the Renaissance. More recently there has been a movement to refute this view. As Professor Butterfield puts it:

The scientific revolution outshines everything since the rise of Christianity and reduces the Renaissance and Reformation to the rank of mere episodes, mere internal displacements, within the system of medieval Christendom. Since it changed the character of men's habitual mental operations even in the conduct of the non-material sciences, while transforming the whole diagram of the physical universe and the very texture of human life itself, it looms so large as the real origin both of the modern world and of the modern mentality that our customary periodisation of European history has become an anachronism and an encumbrance.³

It is not our purpose to trace in any detail the history of the scientific revolution. We simply want to concentrate on the work of the leading contributors to this revolution and by so doing illustrate those traits and methods that most would agree could be called essential parts of the scientific endeavor. For it is in this period which gave birth to modern science that we should be able to find and isolate its essential characteristics and attributes.

To talk about the scientific revolution is to talk about the overthrow of Aristotelian physics, for it was the ideas of Aristotle

that held the day for two thousand years. Aristotle's physics was an integral part of his whole philosophical system, and so not only could he describe how a planet moved around the earth, he could explain why it did so. We need to deal with only two aspects of his physics.

1. In the Aristotelian universe the earth is at the center. And what other place could there be for Man than a geocentric, ego-centric world? But it made sense--for look about you. All heavy things near the earth's surface fall straight down, toward the center of the earth. The sun rises in the east in the morning, traverses the sky, and sets in the west in the evening only to complete the other half of its daily motion that night and then rise once again the following morning. The moon, the five wandering planets, and all the stars do the same. Just watch them. They rise in the eastern sky each night and set in the western sky each morning. This is one of the advantages of Aristotelian physics; it agrees with common sense. Now it is true that if you carefully watch the motions of these heavenly bodies, you soon discover that the moon does not quite make one revolution per day, that the planets seem to "play" (e.g., there are periods during the year when Venus is a morning star and other times when it is an evening star), and that during the course of a year different constellations appear throughout the night. But these discrepancies do not mar Aristotle's cosmology, and they were all wielded together by the Egyptian astronomer Ptolemy in the second century A.D. into a coherent system.
We should pause here and remark about the difference between Aristotle's cosmology and Ptolemy's astronomy. For a split occurred in the development of scientific thought between the time of Aristotle and that of Ptolemy that caused a divorce between physics and astronomy that was to persist for fifteen hundred years. Aristotle had devised a theory of homocentric spheres which carried the heavenly bodies, and with this mechanical model he was able to both describe and explain the motions of the heavens. Like any theory it sought to bring order to the wild diversity found in nature. It provided man with a world-view and gave meaning to the physical universe and man's place in it.

...an astronomer who believes in the validity of the two-sphere universe will find that the theory not only provides a convenient summary of the appearances, but that it also explains them, enabling him to understand why they are what they are. Words like "explain" and "understand" apparently refer simultaneously to the logical and psychological aspects of conceptual schemes. Logically, the two-sphere universe explains the motions of the stars because the motions can be deduced from the far simpler model. Complexity is reduced, and such logical reduction is one essential component of explanation. Aristotle was not only interested in how the planets move, he also wanted to know why they move the way they do. Ptolemy on the other hand seemed primarily concerned with simply how the celestial bodies move. His work was an attempt to solve the so-called problem of

Plato: How can we save the appearances of the skies, i.e., how can we explain the motions of the planets using circular motion?

The astronomer "saved" the phenomena if he succeeded in inventing a hypothesis which resolved the irregular motions of the planets along irregularly shaped orbits into regular motions along circular orbits—regardless whether the hypothesis was true or not, i.e., whether it was physically possible or not. Astronomy, after Aristotle, becomes an abstract sky-geometry, divorced from physical results. Its principal task is to explain away the scandal of non-circular motions in the sky. It serves a practical purpose as a method for computing tables of the motions of the sun, moon and planets; but as to the real nature of the universe, it has nothing to say.5

This is precisely what the Ptolemaic system of epicycles did. It described the motion of the heavens remarkably well and predicted celestial events such as eclipses to a high degree of accuracy, but had little to say about the nature of the real world. Astronomy had become, as Koestler said, a mere geometry of the skies.

Celestial bodies, then, travel in circles for that is the most perfect of geometrical curves and the only one appropriate for these quintessential objects that display no imperfections. "Circular motion has no beginning and no end; it returns into itself and goes on forever; it is motion without change."6 Thus, whereas the natural motion of heavy objects on the earth is straight down towards


6Ibid., p. 60.
its center, the natural motion of celestial objects is circular.

2. In order for an object to move at a constant speed, a constant force is necessary. This is the kernal of Aristotelian dynamics, and, once again, it agrees thoroughly with common sense. For a cart to move along a road at a constant speed the horse must pull it with a constant force. In order to move a book across the table at a constant speed you must push it with a constant force. This law only applies to unnatural motion, i.e., motion not toward the center of the earth. A freely falling object falls naturally toward the earth's surface and no force is required. By the way, it was realized by the Greeks that a freely falling object speeds up as it gets nearer the earth's surface. This was easy enough to explain. For just as a weary traveler hastens his pace as he nears his destination, so a rock speeds up its motion as it approaches its natural dwelling place, the earth's surface.

The overthrow of these two tenacious concepts is what was accomplished by the four men whose work we now want to briefly examine: Copernicus, Kepler, Galileo, and Newton.

If you are partial to dates, and dates are useful benchmarks, then we could say that 1543 marked the beginning of the scientific revolution. In that year two books appeared that were to cast grave doubts on existing scientific thought. One was a book that looked inward to the anatomical structure of man and the other was a book that looked outward to the astronomical structure of the universe in which man lives. Andreas Vesalius' book De Humani
Corporis Fabrica is a book of copious and beautiful illustrations of the anatomical features of man in which many of the details refute the teachings of the Greek physician Galen who lived in the second century A.D. These refutations could be made because Vesalius based his studies on the observations of actual dissections of the human body which was not, up till then, a typical mode of investigation. Before his book appeared students of medicine resorted to the writings of the ancient master Galen whose studies were largely based on the anatomy of apes, not humans. The normal means of instruction was for the students to watch a barber-surgeon dissect on a cadaver as the professor read from Galen.

The other revolutionary book to appear that year was De Revolutionibus Orbium Caelestium written by the Polish priest, Nicholas Copernicus. In this book Copernicus advanced the theory that the sun, and not the earth, was the center of the universe. The Copernican theory, thus, not only shattered the idea that the earth is the center of the universe but, as a consequence of this, man found himself occupying no unique position in the scheme of the universe. Man lives on the third of six planets that orbit the sun. This was the germinal idea for what might be called the principle of mediocrity which has proven to be a very useful notion in cosmology. As it has developed, it is simply the idea that there is no preferential position in the universe. The earth is but one of nine planets that orbit the sun. The sun is but one of ten billion stars in the Milky Way, and the Milky Way is but another galaxy in
the realm of galaxies that make up the universe. Man's position is not unique, perhaps not even significant. (Yet to man his existence is everything!)

Copernicus was driven by a desire to create a system that would be simpler than the complex system of deferents, equants, and epicycles that characterized the Ptolemaic system. Specifically, it was the equant, the point set off from the center about which the planets moved, that repulsed Copernicus. Holton quotes Copernicus as follows:

...the planetary theories of Ptolemy and most other astronomers, although consistent with the numerical data, seemed...to present no small difficulty. For these theories were not adequate unless certain equants were also conceived; it then appeared that a planet moved with uniform velocity neither on its deferent nor about the center of its epicycle. Hence a system of this sort seemed neither sufficiently absolute nor sufficiently pleasing to the mind.

Having become aware of these defects, I often considered whether there could perhaps be found a more reasonable arrangement of circles, from which every apparent inequality would be derived and in which everything would move uniformly about its proper center, as the rule of absolute motion requires.7

We see Copernicus groping towards some new point of view, yet clinging to the ancient idea of circularity. This repulsion of Copernicus towards the complex and cumbersome system of Ptolemy's, and his belief that nature must display a greater mathematical simplicity

are direct reflections of how Neoplatonic thought influenced him. It might even be that the Neoplatonic belief in a relation between the sun and God had its effect on the young Copernicus when he was a student in Bologna and Padua. Such ideas were certainly in the air at those centers of learning.

By taking observations handed down to him, and making his own observations, he devised his sun-centered system which, in the end, was almost as unwieldy as the one he had set out to destroy. He even had to resort to the use of epicycles. Not only did the Copernican system not explain or predict celestial events any better than did the Ptolemaic system, there were even sound scientific arguments against it. To begin with, if the earth revolves around the sun, then the measured angle between the earth and a given star should shift somewhat during the course of one-half revolution. (See Figure 1.) This is called stellar parallax and, because it was not observed in Copernicus' time, he concluded correctly that the distance to the stars must be many times greater than the earth-sun distance. In his words:

...the dimensions of the world are so vast that though the distance from the sun to the earth appears very large compared with the size of the orbs of some planets, yet compared with the dimensions of the sphere of fixed stars, it is as nothing.8

He was correct for the stars are so far removed from the solar system that telescopic observations are required to detect this phenomena. Such observations were not made until three hundred years

8Ibid., p. 133.
The annual parallax of a star. Because the line between a terrestrial observer and a fixed star does not stay quite parallel to itself as the earth moves in its orbit, the star's apparent position on the stellar sphere should shift by an angle \( p \) during an interval of six months. (The earth's orbit is grossly exaggerated with respect to the distance to the star.)


Figure 1

*Stellar Parallax*
after the time of Copernicus. Also, if the earth is traveling through space at the prodigious rate ascribed to by Copernicus, then how could an apple fall from a limb and land on the ground directly underneath? By the time the apple hit the ground the earth would have moved so far that the apple would not even land under the tree. There could be no satisfactory explanation for this without the principle of inertia, and Galileo was still a half-century away.

Then there was the classic argument from the Book of Joshua:

Then spake Joshua to the Lord in the day when the Lord delivered up the Amorites before the children of Israel, and he said in the sight of Israel, Sun, stand thou still upon Gibeon; and thou, Moon, in the valley of Ajalon.

And the sun stood still, and the moon stayed, until the people had avenged themselves upon their enemies. Is not this written in the book of Jasher? So the sun stood still in the midst of heaven, and hasted not to go down about a whole day.

And there was no day like that before it, or after it, that the Lord hearkened unto the voice of a man: for the Lord fought for Israel.9

Why, then, did Copernicus put the sun at the center of his cosmology? The answer is one that reverberates time and time again through the history of science; he liked it there. It was not so much what we would call scientific reasons as it was for aesthetic reasons. It was an act of the poet, a leap of faith into the unknown. A leap, though, that was to be vindicated, for it turned out that the attempt to simplify was in agreement with nature. Copernicus put it this way:

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In the midst of all, the sun reposes, unmoving. Who, indeed, in this most beautiful temple would place the light-giver in any other part than that whence it can illumine all other parts?...

In this orderly arrangement there appears a wonderful symmetry in the universe and a precise relation between the motions and sizes of the orbs which is impossible to obtain in any other way.10

Since the Copernican system had little, if any, explanatory or predictive advantage over the geocentric theory, and since, in fact, there were good arguments against it, it is no wonder that the heliocentric theory won few converts. But Copernicus had ignited an idea, and those after him were forced to consider it. Man's view of the world could never again be the same. Thomas Kuhn speaks of this in his book as follows:

... The very ease and rapidity with which astronomers saw new things when looking at old objects with old instruments may make us wish to say that, after Copernicus, astronomers lived in a different world.11

Kuhn says that science does not always develop in the logical step-by-step fashion that science textbooks would have us believe. During most time periods science does develop in a logical, cumulative manner. But every so often, during those periods which he calls normal science when accumulation is occurring through puzzle and problem solving and through articulation, there develops an anomaly within

10 Holton, op. cit., p. 131.

the old framework of thought. A new way of looking at the world is called for. It is these shifts—revolutions—that are non-cumulative. Kuhn says:

...Sometimes a normal problem, one that ought to be solved by known rules and procedures, resists the reiterated onslaught of the ablest members of the group within whose competence it falls....When the profession can no longer evade anomalies that subvert the existing tradition of scientific practice—then begin the extraordinary investigations that lead the profession at last to a new set of commitments, a new basis for the practice of science.12

These extraordinary episodes are what Kuhn calls scientific revolutions, and certainly the work of Copernicus initiated such a movement. The scales had fallen from the eyes of Copernicus, and he saw a different world which men after him would have to inhabit.

One believer in the Copernican system was the Italian, Giordano Bruno, who postulated an infinite universe in which the stars are suns themselves ruling their own planetary systems. In such a plurality of worlds could there not exist other races of men? If so, would not such men also be apt to fall into sin and need God's redemption? But this would result in a universal peace corps of personal Saviors populating the heavens. Now, if the postulation of a plurality of worlds is not heresy, certainly an unlimited number of Sons of Gods is. For this Bruno was burned at the stake by the Roman inquisition in 1600.

12Ibid., pp. 5-6.
Another devout believer in the Copernican theory was the German astronomer-astrologer Johannes Kepler. Kepler symbolizes the transition of his times. On the one hand he was steeped in the mysticism of the ancient Pythagoreans and he made his living casting horoscopes for the royalty of central Europe. On the other hand, his insistence on accurate astronomical data and his belief in the underlying mathematical structure of the world characterized him as one of the main participants in the scientific revolution. Arthur Koestler, in his book *The Sleepwalkers*, said of Kepler that he stood astride a watershed, one foot in the medieval period and the other firmly planted in the modern epoch.

It is one of the quirks of the history of science that the man who was to formulate the laws of kinematics for the solar system was too myopic to make accurate astronomical observations himself. Kepler had to rely on the observations of others, primarily those of the Dane Tycho Brahe. Brahe had amassed a fortune of observations on the motions of the planets at his Uraniburg observatory on the isle of Hveen. The accuracy of his observations were unmatched due to the superb quality of his instruments, and most would agree that Tycho was the greatest observational astronomer prior to the invention of the telescope. But if Tycho was an observer, a collector, a classifier, Kepler was first and foremost a mathematician intent on a search for harmony and order in the heavens. Kepler was strongly influenced by Neoplatonic thought and he never wavered from his belief in a sun-centered universe. Koestler says that Kepler believed
...that the sun must be in the centre of the world be­cause he is the symbol of God the Father, the source of light and heat, the generator of the force which drives the planets in their orbits, and because a sun-centered universe is geometrically simpler and more satis­factory. 13

Though his work was grounded on accurate observations and though his methodology reflects a strong commitment to mathematical techniques, nevertheless Kepler was a mystic at heart. He believed in the horo­scopes he cast, he believed in the Pythagorean magic of numbers, and he, even more than Copernicus, believed in the inherent beauty and simplicity of nature.

Kepler was driven even more than Copernicus by a mystical semi-religious fervour—a passion to un­cover the magic of mere numbers and to demonstrate the music of the spheres. 14

Coupled with this passion for hidden numbers was also a belief in causal laws that govern the motions of the planets. With this commitment to actual physical laws acting within the universe Kepler was able to reunite the marriage between physics and astronomy that had been torn asunder for so many centuries. Since Ptolemy the task of the astronomer had been to observe, describe, and predict, not to search for causes. Kepler not only wanted to describe the motions of the planets, he wanted to know why they move the way they do.

For the first time since antiquity, an attempt was made not only to describe heavenly motions in geomet­rical terms, but to assign them a physical cause. We have arrived at the point where astronomy and

14 Butterfield, op. cit., p. 63.
physics meet again, after a divorce which lasted for two thousand years. This reunion of the two halves of the split mind produced explosive results. It led to Kepler's three Laws, the pillars on which Newton built the modern universe.\textsuperscript{15}

Taking Tycho's observations on the orbit of Mars, Kepler tried again and again to fit them into the circular orbit demanded by the Copernican system, but to no avail. At one point the discrepancy between the theoretical orbit of Kepler and the observed orbit as made by Brahe was but eight minutes of arc. But so strong was Kepler's faith in the accuracy of Tycho's data that he finally abandoned the circular orbits that had been so sacred to astronomers for over two thousand years. After years of struggling through the maze of Tycho's data and through the labyrinth of his own figures and equations, he finally, in "a true sleepwalker's performance," hit upon the correct curve that matched with Tycho's observations: an ellipse. This is Kepler's first law of planetary motion, that all planets travel in elliptical orbits about the sun with the sun occupying one focus.

His search for a relationship between the sun-planet distance and the orbital speed of the planet led him to his second law.

In its origin the Second Law is independent of any but the crudest sort of observation. It arises rather from Kepler's physical intuition that the planets are pushed around their orbits by rays of a moving force, the \textit{anima motrix}, which emanates from the sun...the number of rays that impinged on a planet and the corresponding force that drove the planet around the sun would decrease as the distance between the planet and the sun increased.\textsuperscript{16}

\begin{itemize}
  \item[\textsuperscript{15}] Koestler, \textit{op. cit.}, p. 258.
  \item[\textsuperscript{16}] Kuhn, \textit{The Copernican Revolution}, p. 214.
\end{itemize}
By such reasoning, and again, by another sleepwalking performance
in which certain mistakes canceled out other mistakes, Kepler hit
upon his so-called second law (it was actually found before the first
law). The second law is that a radius vector drawn from the sun to
the planet in question sweeps out equal areas in equal intervals of
time. Thus, a planet moves faster when it is near the sun than it
does when it is farther away from the sun.

Moreover, should there not be a simple and satisfying relation
between the period of a planet and its distance from the sun? The
third law, often called the Harmonic Law because it establishes
such an elegantly simple rule among the planets, was especially
pleasing to Kepler. It states that the ratio of the square of the
period of revolution of any given planet to the cube of the mean
radius of orbit of that planet is a constant. These three laws are
summarized in Figure 2.

Kepler had found law and order among the planets. He had, as
Professor Butterfield put it, "reduced to order the chaos of data
left by Tycho Brahe, and added to them just the thing that was needed—
mathematical genius."\textsuperscript{17} As with the revolutionary theory of Copernicus,
so the work of Kepler caused people thereafter to look upon the world
with fresh new eyes. No longer could there be any doubt that the
world was, in essence mathematical. This ancient Pythagorean belief

\textsuperscript{17}Butterfield, \textit{op. cit.}, p. 63.
(a) First Law
The planets travel in elliptical orbits about the sun with the sun at one foci. (The eccentricity is greatly exaggerated as the orbits are nearly circular.)

(b) Second Law
If the time it takes the planet to move from point A to point B is the same as it takes to go from point C to point D, then area ABS is equal to area CDS.

(c) Third Law
If T is the period of revolution for a given planet and R is the mean distance from that planet to the sun, then for all planets
\[ \frac{T^2}{R^3} = \text{Constant} \]

Figure 2
Kepler's Three Laws
was ushered back into the modern world by Kepler, and henceforth, any physical theory must ultimately be stated in mathematical terms. (Of course we are using a high metaphor when we say that the world is mathematical. Science seeks quantitative laws which, by definition, require mathematics. But the laws are factual—not mathematical.) Though Kepler was able to describe the motions of the planetary bodies mathematically, he was not able to explain the cause of their motions in a mathematical sense. His kinematics was sound but his dynamics needed more polish. Kepler was sure that a sun-centered force caused the planets to move in their orbits, and he even spoke of bodies mutually attracting one another through space, but he could not formulate the force law. That had to await the genius of another man a half-century later. When Newton's time came his grand synthesis was able to lay, in a deductive fashion, three golden eggs: Kepler's three laws of planetary motion. But first we must deal with another of the giants on whose shoulders Newton was to stand, the father of modern physics, Galileo Galilei.

Galileo was born the same year as Shakespeare (1564) and died the year Newton was born (1642). He was a contemporary of Kepler and corresponded with him. If we can speak of Kepler as a transitional figure with one foot in the medieval period and one in the modern, then Galileo comes across as a thoroughly and frighteningly modern figure. His books are written in the common language of his countrymen. His arguments are straightforward and hardhitting; little wonder that he earned the nickname of "the wrangler." His design and use of experimental apparatus, his reliance on accurate observations
and measurements, his innovation of Gedanken experiments, his combination of both inductive and deductive approaches to problems, and his firm belief in the mathematical reality of nature defined the methodology for all who would seek the hidden laws of nature. There was little of the mystic in this man.

He was utterly devoid of any mystical, contemplative leanings, in which the bitter passions could from time to time be resolved; he was unable to transcend himself and find refuge, as Kepler did in his darkest hours, in the cosmic mystery. He did not stand astride the watershed; Galileo is wholly and frighteningly modern. 18

One of the central theses in Koestler's book, "is the unitary source of the mystical and scientific modes of experience; and the disastrous results of their separation." 19 Kepler is the hero of Koestler's book for he personifies this unity; Galileo, the villain, because he sought to break the unity.

We need to deal with only two aspects of Galileo's work, his telescopic discoveries and his statement of the principle of inertia. These are, however, two of the most important aspects of his work, and together they will suffice to topple the key theorems of Aristotelian physics that we listed earlier. Keep in mind that up until Galileo there had been little direct evidence to refute the teachings of Aristotle. We have seen that the theory of Copernicus was primarily

18 Koestler, op. cit., p. 363.
19 Ibid.
an act of the imagination, and that it explained little, if anything, which a geocentric theory could not explain. It is true that the mathematical laws of Kepler lent strong support to the heliocentric universe, but due to the very nature of the three laws they were not intellectually accessible to most people.

Then in 1609 an event happened that literally was to display the new cosmology to the eyes of anyone who cared to look. In that year Galileo procured a new optical instrument that magnified distant objects, and turned the instrument toward the heavens. Think of the bewilderment, the wonder, splendor, and awe that must have filled that lucky man's mind as night after night new discoveries leaped into the field of view. The heavens were supposed to be perfect, unblemished, but here were black spots on the sun (by means of which he measured the rotation rate of the sun) and pock marks and peaks (whose height he was able to measure) on the surface of the moon. Even Saturn had "ears" sticking out on both sides of the planet (for Galileo's primitive telescope could not resolve the planet's beautiful rings). Venus went through phases just as our moon does, and these phases are neatly and uniquely explained within the Copernican system. (See Figure 3.) But the most fascinating discovery was when Galileo trained his little telescope on the giant planet Jupiter, and here, over a few nights observations, found four star-like objects spinning in a regular pattern about the planet. Galileo had found a system within a system, the moons of Jupiter orbiting about the mother planet. Here was visual
The phases of Venus in (a) the Ptolemaic system, (b) the Copernican system, and (c) as observed with a low-power telescope. In (a) an observer on the earth should never see more than a thin crescent of the lighted face. In (b) he should see almost the whole face of Venus illuminated just before or after Venus crosses behind the sun. This almost circular silhouette of Venus when it first becomes visible as an evening star is drawn from observations with a low-power telescope on the left of diagram (c). The successive observations drawn on the right show how Venus wanes and simultaneously increases in size as its orbital motion brings it closer to earth.

proof that not all bodies orbit the earth, at least not directly. Diplomatically he named these moons the Medicean stars in honor of that great family of Florence. But most of his learned colleagues refused to look through his "optical illusion tube." He wrote to Kepler asking whether they should laugh or cry at the stubbornness of the philosophers:

What is to be done? Let us laugh at the stupidity of the crowd my Kepler...How you would shout with laughter, my dearest Kepler, if you were to hear what the chief philosophers of Pisa said against me to the Grand Duke.20

The telescope served as a battering ram against many of Aristotle's cosmological concepts, and Galileo's telescopic discoveries provided strong support for a heliocentric universe. Though one could argue that Galileo's discoveries did not prove the validity of the Copernican scheme, they certainly were good propaganda.

However, it is in the arena of physics that Galileo was most adept and formidable. Recall that in Aristotelian physics a constant force is required to provide constant motion. Also, that one of the arguments used against the Copernican system was that if the earth is moving swiftly through space in its orbit about the sun, then how could an apple land directly under the bough from which it fell? With one clean swoop Galileo demolished both of these views. In so doing he provided Newton with what is now called Newton's first law of motion. Galileo accomplished this by means of an elegantly simple

20 Ibid., p. 376.
Gedanken experiment—a thought experiment. Such an experiment is one performed not with real experimental apparatus, but simply in the mind of the experimenter. There is one qualifying requirement: it must not violate any known law of nature. Usually Galileo would attempt such experiments with actual equipment as far as possible. It is worth discussing this particular experiment in some detail. Here is what Galileo wrote concerning the experimental setup:

A piece of wooden moulding or scantling, about 12 cubits long, half a cubit wide, and three finger-breadths thick, was taken; on its edge was cut a channel a little more than one finger in breadth; having made this groove very straight, smooth, and polished, and having lined it with parchment, also as smooth and polished as possible, we rolled along it a hard, smooth, and very round bronze ball. Having placed this board in a sloping position, by lifting one end some one or two cubits above the other, we rolled the ball, as I was just saying, along the channel...21

It is obvious that Galileo is trying to eliminate friction. At the bottom of this board was a similar board laid out in a horizontal position, and at the end of it a third board was inclined at the same angle as the first. (See Figure 4.) The question is, if the ball is released from position A, how high up the opposite incline will it go? With little friction the ball should attain its original height, position B. But now what if we incline the third board at a smaller angle as shown in Figure 4(b)? How far up the incline will the ball go? The answer is again B, but this time it must travel a greater

Figure 4
Galileo's Gedanken Experiment
horizontal distance in attaining its original height. Then we go to Figure 4(c). How far will the ball go now? As Galileo immediately grasped, the ball must go on forever assuming there are no net external forces acting such as friction. Galileo put it this way:

Furthermore we may remark that any velocity once imparted to a moving body will be rigidly maintained as long as the external causes of acceleration or retardation are removed, a condition which is found only on horizontal planes...from this it follows that motion along a horizontal plane is perpetual; for if the velocity is uniform, it cannot be diminished or slackened, much less destroyed.22

This is Galileo's statement of the law of inertia, about which Whitehead once remarked, "It should be set to music and chanted in the halls of universities."23 Because Galileo lived on a round earth, he could picture such an object as traveling only in a circle. Even Galileo could not throw off the ancient yoke of circularity. It was left to Descartes, who could envision infinite straight line motion, to put the law in its final form.

So Galileo not only saw the heavens with fresh new eyes, he also looked at motion on the earth's surface in a way no one had ever done before. Butterfield put it this way:

In the long run, therefore, we have to recognize that here was a problem of a fundamental nature, and it could not be solved by close observation within the framework of the older system of ideas--it required a transposition in the mind.24

22Ibid., p. 206.

23Holton, op. cit., p. 33.

24Butterfield, op. cit., p. 5.
This would agree with Kuhn's central thesis that we mentioned earlier that "...different generations of scientists see the world in incommensurable ways." Galileo saw past the common-sense view that a constant motion requires a constant force. If you can eliminate the friction between the book and the table (and here, in the Gedanken experiment, was the transposition of the mind), then the slightest initial push will provide the book with a constant velocity. Galileo's insight was to see through to the inner simplicity of nature. The result was a simplification, the act of abstraction. This same approach to physical problems is encountered time and time again throughout the history of science, and is exemplified today by those physicists who search for a unified field theory, i.e., a theory that would account for all four of the fundamental forces in nature by a single, consistent set of equations. The result would be elegantly simple and aesthetically pleasing, but the process demands the maximum of abstract thought.

The principle of inertia also solves the apple problem. Before it fell, apple, tree, and earth were moving along at a constant velocity. As the apple falls, it, like the tree and the earth, continues to move horizontally at the same rate and, thus, lands directly under the limb from which it fell. Thus, another counterargument is removed from the Copernican system. With the statement of the law of inertia all motion at the earth's surface becomes natural. This is contrary to the Peripatetic school which held that only vertical motion was natural at the

earth's surface; all other motion had to be "forced." If motion at the
earth's surface is natural, then perhaps there is nothing so drastically
different between terrestrial physics and celestial physics. For even the
Greeks thought of celestial motion as natural.

Concepts and methods were ripening for the harvest of Newton, in
whose work the scientific revolution would come to fruition. Standing
on the shoulders of those giants who had gone before him, Newton again
transformed the world-view in such a way that it would never appear as
it had before his time. Borrowing freely from the scientific work of
his predecessors such as Copernicus, Kepler, and Galileo, and being in
touch with his great contemporaries on the continent such as Huygens
and Leibniz and with his fellow members of the Royal Society, and com­
bining both the inductive method of Bacon and the deductive method of
Descartes, Newton wrought his own system of the world. But Newton's
work was more than just a synthesis of the work that others had done
before him. It involved a leap of genius, a leap of faith into the
unknown. It was more than a mere increment to existing knowledge. It
involved a new way of looking at the world.

In the half-century between the time of Galileo and Newton the
intellectual and scientific atmosphere in Europe had changed consid­
erably. Whereas Galileo had been forced to recant his views before
the Inquisition, and was held under house arrest during his last years,
by the time Newton reached his old age conditions had changed to the
extent that he was knighted and honored by all of Europe. By
Newton's time scientific societies and journals were appearing in most
countries in western Europe. 'Nullius in Verba,' which had been the
motto of the Royal Society at its foundation in 1660, became a model for the rejection of all authority which was to become axiomatic of eighteenth-century rationalism. It has been said of Newton, who was a shy and introverted man, that had he encountered the wrath and opposition from his state and colleagues with which Galileo had to contend, it is probable he would never have published a line. It is well known that his arguments with Robert Hooke not only caused resentment on the part of Newton but also, undoubtedly, induced a hesitancy to publish. If Hooke could cause these effects, imagine Newton facing the Inquisition.

To illustrate the extent of this man's genius I would like to quote at some length from a memoir left by Newton:

I found the Method [the calculus] by degrees in the years 1665 and 1666. In the beginning of the year 1665 I found the method of approximating Series and the Rule for reducing any dignity of any Binomial into such a series [i.e., he had formulated the Binomial Theorem]. The same year in May I found the method of tangents of Gregory and Slusius, and in November had the direct method of fluxions [the differential calculus], and the next year in January had the Theory of colours, and in May following I had entrance into ye inverse method of fluxions [integral calculus]. And the same year I began to think of gravity extending to ye orb of the Moon, and having found out how to estimate the force with wch globe revolving within a sphere presses the surface of the sphere, from Kepler's Rule of the periodical times of the Planets being in a sesquialterate proportion of their distances from the centers of their Orbs I deduced that the forces wch keep the Planets in their Orbs must [be] reciprocally as the squares of their distances from the centers about wch they revolve: and thereby compared the force requisite to keep the Moon in her Orb with the force of gravity at the surface of the earth, and found them answer pretty nearly. All this
was in the two plague years of 1665 and 1666, for in those days I was in the prime of my age for invention, and minded Mathematicks and Philosophy more than at any time since.26

An amazing accomplishment for a young man of twenty-four. Little wonder that the Marquis de L'Hopital asked--quite seriously--if Newton ate and slept like other mortals. In fact he didn't. Newton lived in rooms provided by his college, Trinity, at Cambridge. Story has it that years later, when he was working on the Principia, Newton would be called to dinner whereupon he would leave his room half dressed, walk out into the street completely lost in thought, return to his room, and then, hours later, ask when dinner would be. Besides, it is a recurrent theme that most of the revolutionary insights in the fields of science and mathematics were brought off by men before their thirtieth birthday.

Though most of his insights came during these youthful years, it was not until 1687 that his Principia was published. It is in this book that Newton used his two force laws to weave together his grand fabric. It is to these two laws that we now address ourselves. There could be some truth to the story that we were all told in school that it was an apple falling on young Isaac's head that first caused him to begin to think about gravity. For could not the same force that causes the apple to fall to the ground also keep the moon in her orb about the earth? Here Newton could make a quantitative check of his hunch. Knowing both the earth-moon distance and the orbital speed of the moon, he could easily calculate how far
the moon "fell" in one second. This distance turns out to be one twentieth of an inch. By utilizing a mathematical technique (part of the calculus which Newton invented for the express purpose of solving such physical problems) he was able to show that a spherical body such as the earth behaves as though all of its mass was concentrated at a point at its center. Newton was also able to show that the gravitational force should fall off inversely with the square of the distance separating two bodies (just as the intensity of light falls off as you move away from the source). Professor Feynman in his 1964 Messenger Lectures at Cornell University completes the argument.

The moon is sixty times as far away from the earth's center as we are; we are 4,000 miles away from the center, and moon is 240,000 miles away from the centre, so if the law of inverse square is right, an object at the earth's surface should fall in one second by 1/20 inch X 3,600 (the square of 60) because the force in getting out there to the moon, has been weakened by 60 X 60 by the inverse square law. 1/20 inch X 3,600 is about 16 feet, and it was known already from Galileo's measurements that things fall in one second on the earth's surface by 16 feet. So this meant that Newton was on the right track, there was no going back now, because a new fact which was completely independent previously, the period of the moon's orbit and its distance from the earth, was connected to another fact, how long it takes something to fall in one second at the earth's surface. This was a dramatic test that everything is all right.27

It was this analysis that caused Newton to write, "...found them to answer pretty nearly."

We cannot go through all the steps that led to the formulation of the universal law of gravitation, though by now it should be clear that some of them transcended strict laws of logic and can only be explained as profound insights made by an envisionary genius. The result can be stated as follows: any two masses in the universe attract each other with a force that is directly proportional to the product of their masses and inversely proportional to the square of their separation. The shorthand of mathematics permits us to state this law succinctly as follows:

\[ F = G \frac{m_1 m_2}{r^2} \]

where \( F \) is the force, \( m_1 \) and \( m_2 \) are the respective masses, \( r \) is the distance of separation, and \( G \) is a universal constant whose value depends on the units chosen. This is the macroscopic force that holds the universe together, the same force that causes planets to orbit the sun and applies to fall to the earth's surface. It was this explanation of both terrestrial and celestial phenomena by means of the same force law that has caused writers to speak of the Newtonian synthesis.

Of course there is more to Newtonian mechanics than this single law. I have already referred to Newton's intellectual debt to other scientists, e.g., to Galileo for the principle of inertia which, through the help of Descartes, Newton was able to reformulate in the *Principia* as:

Every body perseveres in its state of rest, or of uniform motion in a right line, unless it is compelled to change that state by forces impressed upon it.28

Newton was also indebted to Descartes for realizing that "uniform motion in a right line" (we should say constant velocity) is indistinguishable ontologically from rest. Both are states as opposed to processes in the Aristotelian sense and, hence, do not require a cause, or mover, or force. In addition Newton's second law of motion played an essential part in his overall theory. This law, known to every student of physics, states that the acceleration of an object is directly proportional to the net force acting on the object and is inversely proportional to the object's mass. Again in the language of mathematics this can be written:

\[ \mathbf{F}_{\text{net}} = m\mathbf{a} \]

where \( \mathbf{F}_{\text{net}} \) is the net force vector, \( m \) is the mass of object, and \( \mathbf{a} \) is the acceleration vector. This law is the result of the idea fervent in Newton's mind that the secret to mechanics was not to ask what produces constant motion (velocity), but to ask what produces a change in motion (acceleration). For Aristotle a constant force is necessary to produce a constant velocity for an object horizontal to the earth's surface. For Galileo no force at all is needed for such motion provided friction is eliminated. But what happens when a net force is applied to such an object? It was Newton's answer to this question that takes the form of his second law of motion. (His first law is the statement of the principle of inertia.) So for Newton, too, the scales fell from his eyes, and he saw the world in a new way.

Armed with this arsenal of concepts and methods, Newton was able to embrace into his system of thought a wealth of diverse
phenomena in both physics and astronomy. As mentioned earlier, Kepler's empirical laws can be deduced neatly from the work of Newton. Consider the third law—the harmonic law—which states the relation between the period, $T$, of a planet and its distance, $R$, from the sun.

\[
\frac{T^2}{R^3} = K
\]

where $K$ is a constant for all planets. Newton knew that it was the sun's force of gravity that was holding the planets in their orbits. Without such a force the planets would move off in uniform straight line motion obeying the law of inertia. To remain in orbit a centripetal force must keep pulling the planet in towards the sun. This centripetal force, the expression for which is

\[
F_c = \frac{m4 \pi^2 R}{T^2}
\]

where $m$ is the mass of the planet, is just the force of gravity. That is

\[
F_c = F_g
\]

or

\[
\frac{m4 \pi^2 R}{T^2} = \frac{GmM}{R^2}
\]

therefore

\[
\frac{T^2}{R^3} = \frac{4 \pi^2}{GM}
\]
or

\[ \frac{T^2}{R^3} = K \]

where \( K = \frac{4\pi^2}{GM} \) is a constant since \( M \), the mass of the sun, remains the same for all planets. And this is Kepler's third law. In this derivation we have assumed uniform circular motion for the planets. At this stage this might seem ludicrous since one might say that it was Kepler's lifetime work to prove that the orbits are not circular but elliptical. However, the error involved in assuming circular orbits is very small. In fact, one might say, it is simply because the planetary orbits are so nearly circular that Kepler had such a torturous time in proving them elliptical.

Newton was also able to explain such diverse phenomena as the nature of the tides and the periodicity of the great comet that appeared in 1682 (which was named after his friend Edmund Halley). Einstein once said of Newton, "Nature to him was an open book, whose letters he could read without effort." \(^{29}\) Balanced with such profound insights into the nature of the physical universe, Newton remained throughout his life a deeply religious man. Though strongly influenced by Descartes, Newton did not like the Frenchman's brand of materialism. Koyre uses a quote from Newton in his book:

...materialism that banishes from natural philosophy all teleological questions, that reduces everything to blind necessity, which obviously cannot explain the variety

and the purposeful structure of the universe, "whereas the main business of Natural Philosophy is just to ask these questions and, without feigning hypotheses, deduce causes from effect till we come to the very first Cause which is certainly nonmechanical."30

For three hundred years Newtonian mechanics has served as a model for what a scientific theory should be like. The history of physics during the eighteenth century is little more than a history of the refinement of Newtonian mechanics by such mathematical physicists as Gauss, Lagrange, and Laplace. It was during this time that the universe became viewed as a vast machine running like clockwork according to the laws of Newton. Story has it that Napoleon, upon having the work of Laplace explained to him, asked Laplace why he took no account of God in his system. To which Laplace is said to have replied, "I had no need of that hypothesis." Though new fields were opened up and great strides taken in areas such as optics, electrodynamics, and thermodynamics during the nineteenth century, the laws of Newton remained intact and continued to serve as a model for physical law. In fact, it was during the first half of the nineteenth century that one of the most remarkable and fruitful applications of Newtonian mechanics took place. Working from the perturbations of the recently discovered planet Uranus, astronomers using the laws of Newton predicted the existence of another planet outside the orbit of Uranus. The same night that he received the calculations on the position of the predicted planet, an observer at the observatory in Berlin discovered the planet Neptune.

It was not until the present century that two revolutions have occurred which have shaken the very foundations of Newtonian mechanics. The first of these was the special theory of relativity proposed by Albert Einstein in 1905. This theory forced a complete change in the way man was to view such fundamental concepts in physics as time, space, and mass. At ordinary velocities the laws of Newton remain perfectly valid, but at velocities approaching the speed of light Newtonian mechanics breaks down and the new transformation of Einstein must be invoked. Though most physicists view Newtonian mechanics as a limiting case of relativistic mechanics, Kuhn sees a more drastic difference:

For in the passage to the limit it is not only the forms of the laws that have changed. Simultaneously we have had to alter the fundamental structural elements of which the universe to which they apply is composed. . . . Just because it did not involve the introduction of additional objects or concepts, the transition from Newtonian to Einsteinian mechanics illustrates with particular clarity the scientific revolution as a displacement of the conceptual network through which scientists view the world.31

The other revolution occurred during the mid-twenties and was the work of a number of men. Just as relativity caused man to alter such ontological concepts as space and time, so quantum mechanics forced an alteration in the epistemological concept of causality. In Newtonian mechanics, if we have an isolated system of particles whose masses,

31 Kuhn, op. cit., p. 102.
positions, and velocities are known at an initial time, then, if the system is closed, the positions and velocities at any future time can be predicted. This is the deterministic nature of classical physics, which caused the eighteenth century rationalists to view the universe as a giant clockwork. In actuality the complexity of a given configuration of a system might make the calculation impossible, but only in practice, not in principle. According to quantum mechanics such a calculation is impossible in principle. Given the configuration and statistical state description of a system at some initial time, all we can do is compute a most probable state description at any given later time. It is even impossible to measure both the velocity and position of a single particle with unlimited precision at any given instant. Such measurements are governed by an inherent uncertainty. We are not talking about uncertainties due to experimental error, we mean an uncertainty in principle. Man's knowledge of the physical universe is limited. It is limited due to an uncertainty inherent in the nature of any measurement, e.g., due to the diffraction of electromagnetic radiation. This uncertainty is governed by a tiny universal constant known as Planck's constant.

... One could speak of the position and of the velocity of an electron as in Newtonian mechanics and one could observe and measure these quantities. But one could not fix both quantities simultaneously with an arbitrarily high accuracy. Actually the product of these two inaccuracies turned out to be not less than Planck's constant divided by the mass of the particle.32

It is easy to show mathematically that for the systems we encounter in our everyday lives this principle of uncertainty is completely insignificant, and that the laws of classical physics are perfectly valid. It is only when dealing with systems in which Planck's constant becomes important, e.g., in atomic systems, that quantum mechanics must be used. But just as relativity caused man to view the world differently, so quantum mechanics demands a change in our world view. No longer is nature thought to be based ultimately on causal laws, for, at least at the atomic level, the old laws of cause and effect are inept.

...we cannot--and this is where the causal law breaks down--explain why a particular atom will decay at one moment and not at the next, or what causes it to emit an electron in precisely this direction rather than that. And we are convinced, for a variety of reasons, that no such causes exist.33

We have looked at four of the major contributors to the scientific revolution of the sixteenth and seventeenth centuries. Certain characteristics have appeared repeatedly in these historical studies. It is postulated that these features are characteristic of science in general. This chapter is concluded by listing those characteristics that seem to be common to the scientific endeavor. These five characteristics will be used in the analysis of the three studies in education that will be described in Chapter III.

Characteristics common to the scientific endeavor:

1. A science should be grounded on experimentation and/or observation. Recall that Kepler discarded his circular orbits when they disagreed with Brahe's data. Max Born, one of the contributors to the development of quantum mechanics, put it this way:

...My advice to those who wish to learn the art of scientific prophecy is not to rely on abstract reason, but to decipher the secret language of Nature from Nature's documents, the facts of experience.34

2. Patterns must be discovered that become the laws of science. These laws of science should be elegant and aesthetically pleasing. Let me try to explain that. The search for rational explanations of natural phenomena lead men to the discovery of laws of science. These laws should encompass a vast spectrum of phenomena and reduce the wild diversity displayed in nature to a few succinct statements. They reduce chaos to order and harmony. For example, Newton's laws encompass a broad range of diverse phenomena and account for them by means of a few mathematical statements. This reduction results in a wonderful economy of thought. How can this be? Perhaps, as Feynman says, "...it is because nature has a simplicity and therefore a great beauty."35 In physics these laws invariably take on a mathematical form. But there are laws of nature that are not that way. For example, Galileo's principle of inertia was not stated in a mathematical form, though it could be after Newton's work. Galileo knew, though, that the language of nature was mathematics. The law of natural selection in biology or

34Max Born, Experiment and Theory in Physics (Cambridge: Cambridge University Press, 1943), p. 44.

35Feynman, op. cit., p. 173.
the principle of uniformitarianism in geology are two more examples of natural law stated in non-mathematical terms. Yet both of these laws reduce their respective realms of nature to a few clear and concise ideas. That is why they are elegant and beautiful.

3. A science must be able to do more than describe and predict phenomena. It should also be able to offer rational explanations of the phenomena under investigation. A purely descriptive classification of the heavenly bodies and their motions hardly constitutes a science. This is why Kepler's work was more scientific than Ptolemy's. Kepler not only wanted to describe the motions of the planets in a way that would be consistent with the data, he also wanted to know why they moved in the manner they do. These questions of how and why lead to theories whose task it is to explain the phenomena—in addition to being descriptive and predictive. A little girl's question to her mother, "Mommy, why does it rain?", is a very scientific question. Science should increase man's understanding of the world he lives in.

4. A science must gather consensus among as many of its practitioners as possible, i.e., the laws of nature must be agreed upon by the community of scientists. As Ziman says, "The objective of science is a consensus of rational opinion over the widest possible field." 36 This means that the experiments and/or observations that led to the laws must be repeatable and confirmable by other scientists. Though Kepler's laws met with considerable resistance

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at first, once his data and calculations were checked by other astronomers, his laws were confirmed. If charmed particles are detected at the Fermi National Accelerator Laboratory, then these particles must be confirmed at other laboratories capable of conducting such an experiment.

5. The laws of science are subject to change, at least subject to being refined or extended. Normally the laws of science provide a framework in which science proceeds through accumulation and articulation. Sometimes, though, an anomaly occurs which calls for a new way of looking at the world. Kepler could not account for circular orbits using Brahe's data, and this caused his conversion. After Kepler the world was never the same. The shift in the scientific framework caused by Kepler's conversion was non-cumulative and is an example of what Kuhn refers to as a paradigm shift. These periodic upheavals (Kuhn calls them revolutions) are characteristic of science.
CHAPTER III

STUDIES IN EDUCATION

This chapter is a description of three studies in education. Although the three studies are not intended to be related to each other, all three are experimental studies. No analyses or comments of these studies are made in this chapter. Chapter IV will attempt an analysis of these three studies with respect to the list of characteristics of the scientific endeavor established in Chapter II. The three studies described in this chapter are as follows: The Pygmalion Effect by Rosenthal and Jacobson; Effects of Accelerating Bright Older Pupils from Second to Fourth Grade by Klausmeier; Teacher Influence, Pupil Attitudes, and Achievement by Flanders.

I

The Pygmalion Effect

In Greek mythology Pygmalion was a sculptor living on the isle of Cyprus and who despised women. He carved out of ivory a beautiful statue of a woman which represented all the qualities he longed for in a woman but knew could never exist. So beautiful was his creation and so intense were his yearnings for such a woman that he fell in love with the statue. He prayed to the goddess Aphrodite to
give life to his statue and she granted his request. Thus the qualities that he had attributed to his ideal woman became a reality.

This myth is an example of a self-fulfilling prophecy.

The essence of this concept is that one person's prediction of another person's behavior somehow comes to be realized. The prediction may, of course, be realized only in the perception of the predictor. It is also possible, however, that the predictor's expectation is communicated to the other person, perhaps in quite subtle and unintended ways, and so has an influence on his actual behavior.¹

Such was the case for Liza in George Bernard Shaw's Pygmalion. Liza, in addressing her friend Pickering, says:

You see, really and truly, apart from the things anyone can pick up (the dressing and the proper way of speaking, and so on), the difference between a lady and a flower girl is not how she behaves, but how she's treated. I shall always be a flower girl to Professor Higgins, because he always treats me as a flower girl, and always will; but I know I can be a lady to you, because you always treat me as a lady, and always will.²

Self-fulfilling prophecies seem prevalent among human relationships. Consider the parent-child relationship. If the parent believes in original sin, that evil lurks in every alleyway, and that children walk a very thin line between heaven and hell, then it seems likely that not only will such a parent suffer from insomnia, but that, indeed his children will fall into trouble. On the other hand,


if the parent believes in the basic goodness of man, trusts his children, and deals with them in a positive fashion, then it seems that a healthy relationship will be fostered between the parent and the child, and that it is less likely that the child will fall into any serious trouble. Or take the physician-patient relationship. You go to a doctor with respect to a nagging backache. If the doctor, after examining you, tells you that this, indeed, could develop into something serious, that you should commence taking three different types of medication immediately, and that you should report back to him for weekly checkups, then it is highly probable that you will walk out of his office feeling worse than when you walked in. On the other hand, if the doctor, after his examination, says it is nothing, that you just need to get out in the fresh air, relax, and enjoy life, then it is more than likely that before long your backache will improve.

Now, consider the teacher-student relationship. There are undoubtedly many reasons why children from lower social and economic backgrounds do poorer in school than children from "the right side of the tracks." One reason might be that their teachers do not expect them to achieve as well as children from middle and upper-middle class families, and, somehow, this expectancy is fulfilled. If a teacher expects the students to be uninterested in learning, mischievous, and underachievers, then they will be. But if the teacher expects his or her students to be interested in learning, bright, good human beings, then they will be. In either case they will fulfill
the expectancy, or prophecy, of the teacher. It is on this concept of self-fulfilling prophecies that the study of Rosenthal and Jacobson is based.

One of the investigators, Rosenthal, an experimental psychologist, had done a series of experiments with rats which tended to support the above hypothesis. In the experiment ten rats of the same strain were divided into two groups of five each and given to two groups of experimenters. One group was told that their rats were adept at running a maze and the other group was told that their rats were 'slow-learners' at running a maze. In truth neither group had shown superior ability in maze running. The experimenter's task was to teach the rats to run the maze. The result was that the group of rats that were supposed to perform better did perform better, and the group that had been designated as the 'slow-learners' did not perform as well.

From the outset the rats believed to have the higher potential proved to be the better performers. The rats thought to be dull made poor progress and sometimes would not even budge from the starting position in the maze. A questionnaire given after the experiment showed that the students with the allegedly brighter rats ranked their subjects as brighter, more pleasant and more likable than did the students who had the allegedly duller rats....The students with the "bright" rats also said they handled their animals more, as well as more gently, than the students expecting poor performances did.3

The scene now shifts to an elementary school in the South San Francisco Unified School District, and the subjects change from experimental rats to the children in kindergarten through grade five at this school. A large percentage of the students attending this school could be called "disadvantaged" children.

The "disadvantaged" child is a Negro American, a Mexican American, a Puerto Rican or any other child who lives in conditions of poverty. He is a lower-class child who performs poorly in an educational system that is staffed almost entirely by middle-class teachers.4

The teachers at the school were not told the nature of the experiment that was to be carried out in their school over a two-year period. In May the teachers gave a standard intelligence test (Flanagan Tests of General Ability) to all pupils from kindergarten through grade five. The purpose of the test was that it would serve as the measuring instrument to compare the expectancy advantage of the children in the experimental group to the children in the control group. "Expectancy advantage was defined by the degree to which IQ gains by the "special" children exceeded gains by the control-group children."5 The following September about twenty percent of the students were randomly chosen and designated as "potential academic spurters." At the beginning of the school year each teacher was given a list of those students in her class that might be expected to show

4 Ibid., p. 19.

high academic gain during the next year or two. This is the only information that the teachers were given. In other words, "The difference between the special children and the ordinary children, then, was only in the mind of the teacher."6

The students were given the same IQ test four months after school started, at the end of the school year, and in May of the following year. The results of the tests seemed to verify the hypothesis of the experimenters: that those students whom the teachers expected to show intellectual gains did so, and those students who were not designated "spurters" did not show as much gain. Thus, the idea of a self-fulfilling prophecy operating within the classrooms appears to be valid. Figure 5 shows the results of the gains in intelligence.

At the end of the year the teachers were asked to describe the classroom attitudes of their pupils. In general the teachers saw the "academic spurters" as

...having a better chance of being successful in later life and as being happier, more curious and more interesting than the other children. There was also a tendency for the designated children to be seen as more appealing, better adjusted and more affectionate, and as less in need of social approval.7

We are reminded of the experiments with rats. In that case the experiments who worked with the more intelligent animals also thought

6Ibid., p. 175.
7Rosenthal, Teacher Expectations for the Disadvantaged, p. 22.
Gains in intelligence were shown by children by the end of the academic year in which the experiment was conducted in an elementary school in the San Francisco area. Children in the experimental group (hashed bars) are the ones the teachers had been told could be expected to show intellectual gains. In fact their names were chosen randomly. Control-group children (light bars), of whom nothing special was said, also showed gains.


Figure 5

Gains in Intelligence
that their animals had better personalities than the slower rats. We notice this same trend with the children in the elementary school. Those designated as academic spurters not only achieved better on test scores, they were also seen by the teachers as having more interesting personalities.

As to what accounts for the results, the experimenters can only advance hypotheses. One might think that the teachers spent more time with the children who were expected to show gain. From questions asked of the teachers, they did not seem to think so. Perhaps the teachers communicate their expectations in non-verbal ways and that these signals (facial expressions, tone of voice, touch) are picked up by the students and influence their behavior. Also, why were the results more pronounced in the first two grades? One reason might be that because they are younger they are more open to receiving the non-verbal cues coming from the teacher which communicates his or her expectancies.

2

**Effects of Accelerating Bright Older Pupils from Second to Fourth Grade**

Children usually begin the first grade at age six and graduate from high school at age eighteen. However, within any given grade there is an age difference among the children of up to one year. Also, within any given grade there are some students who are more academically gifted than others. Thus, in any given grade there are
students who are both older and brighter than their classmates. Why not allow these students to skip a grade so that they will graduate from high school and enter college one year earlier than they would be able to without the acceleration? This eventually permits them to begin their productive careers early.

In order to see what the effects such an acceleration would have on a group of young students, Herbert Klausmeier and Richard Ripple conducted a study in the Racine, Wisconsin, public elementary schools during the 1960-61 academic year. The original study was published in 1962 in the *Journal of Educational Psychology* and was entitled "Effects of Accelerating Bright Older Pupils from Second to Fourth Grade." Follow-up studies were made in 1962 and 1967 and appeared in the 54th and 59th volumes of the above journal. The working question and purpose of the study was stated in the original article by the authors:

> Should not the older bright children be accelerated at some grade or school level so that they may complete high school at least as young as their less able classmates who happened to be born during a month which permitted them to be the younger children when entering the first grade?8

The procedure was that in March, 1960, a group of fifty-two students in the upper half of their grade in chronological age and of superior learning abilities were chosen from the entire second

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grade population of the Racine schools. The instrument used to determine the pupils of superior learning abilities were the Kuhlman-Anderson IQ test, the Elementary Battery of the Metropolitan Achievement Tests, and a recommendation for acceleration from their teachers. These students were then randomly divided into an accelerated experimental group and a nonaccelerated control group. The accelerated students were given an intensive five-week summer course at the end of the second grade which was designed to provide them with the essential material that they would normally have been taught in the third grade. In September, 1960, these students entered sixteen different fourth grade classrooms since no effort was made to keep either the experimental group or the control group together.

In addition to the original control group, which included sixteen girls and ten boys, five additional groups were chosen, each having the same number of students as both of the original groups. These five groups were to serve as additional comparison with the accelerated group. These groups were designated and made up as follows:

3SY - the younger second graders with superior learning abilities who were enrolled as third graders in September, 1960.

4SO - the older third graders with superior learning abilities who were enrolled as fourth graders.

4SY - the younger third graders with superior learning abilities who were enrolled as fourth graders. These students would be up to six months older than the experimental group.
4AO - the older third graders of average learning abilities who were enrolled as fourth graders

4AY - the younger third graders of average learning abilities who were enrolled as fourth graders

The two original groups can be designated and described as follows:

Acc - the experimental group of older second graders who were accelerated to the fourth grade in September, 1960.

3SO - the control group of older second graders with superior learning abilities who were enrolled as third graders in September, 1960.

Comparisons between the experimental group, Acc, and the control group, 3SO, were made in March, 1961, to demonstrate the effects of the acceleration. At the same time comparisons were also made between Acc and the other five groups. This was done to ascertain the extent to which the accelerated group differed from the younger third graders of superior learning abilities, 3SY, and from older and younger fourth graders of average and superior learning abilities. The comparisons were made by the use of nine different measuring instruments. They were as follows:

1. Educational Achievements
2. Attitudes toward School and Learning
3. Problem Solving Ability
4. Ethical Values
5. Handwriting Skills
6. Psychomotor Abilities
7. Intellectual and Affective Characteristics

8. Peer Acceptance

9. Creative Thinking Abilities

The results of these tests are summarized in Tables 1, 2, and 3 all of which are taken from the 1962 article in the *Journal of Educational Psychology*. Table 1 shows the differences between the accelerated group and the six comparison groups on measures where a difference in sex did not lead to a significant difference in results. For example, in Table 1 we note no significant difference between Acc and 3S0 in chronological age, IQ, teacher ratings, and Metropolitan Achievement Test scores. Of course this is what we would expect since it was just these criteria that were used in the selection of those two groups. Tables 2 and 3 show the differences between the accelerated group and the six comparison groups for those measures where a difference in sex did lead to a significant difference in results.

Several statements can be made from these results. For example, from Table 1 one can see that the nonaccelerated control group, 3S0, was not significantly higher than the accelerated group on any of the measures. On four measures Acc was significantly higher than 3S0.

In general, the accelerated pupils (Acc) were significantly higher than the younger third graders of superior learning abilities (3SY), significantly lower than older fourth graders of superior learning abilities (4S0), not significantly different from younger fourth graders of superior learning abilities (4SY), and significantly higher than older and
TABLE 1

Summary of Differences Between the Accelerated Group and the Six Comparison Groups on Measures Where the Interaction Was Not Significant

<table>
<thead>
<tr>
<th>Measure</th>
<th>Not significantly different from</th>
<th>Significantly lower than</th>
<th>Significantly higher than</th>
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<tr>
<td></td>
<td>ACC group</td>
<td>ACC group</td>
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<td>March 1960 measures</td>
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<tr>
<td>Chronological Age</td>
<td>3SO</td>
<td>3SY</td>
<td>4SO,4LY,4AO,4AY</td>
</tr>
<tr>
<td>IQ (Kuhlmann-Anderson)</td>
<td>3SO,4SO,4LY</td>
<td>4AO,4AY</td>
<td>3SY</td>
</tr>
<tr>
<td>Teacher Ratings</td>
<td>3SO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metropolitan Achievement Test-Elementary Battery</td>
<td>3SO</td>
<td></td>
<td></td>
</tr>
<tr>
<td>March 1961 measures</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metropolitan Achievement Test-Intermediate Battery</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arithmetic Computation</td>
<td>4LY,4AO</td>
<td>3SO,3SY,4AY</td>
<td>4SO</td>
</tr>
<tr>
<td>Arithmetic Problem Solving and Concepts</td>
<td>4LY</td>
<td>3SO,3SY,4AO,4AY</td>
<td>4SO</td>
</tr>
<tr>
<td>Attitude toward School, Learning:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Places Liked Best</td>
<td>3SO,3LY,4SO,4LY,4AO,4AY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attitude Inventory</td>
<td>3SO,3LY,4SO,4LY,4AO,4AY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Problem Solving Test</td>
<td>3SO,3LY,4LY</td>
<td>4AO,4AY</td>
<td>4SO</td>
</tr>
<tr>
<td>Ethical Values Inventory:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rational Conscientious</td>
<td>3SO,3LY,4SO,4LY,4AO,4AY</td>
<td></td>
<td>4AO</td>
</tr>
<tr>
<td>Irrational Conscientious</td>
<td>3SO,3LY,4SO,4LY,4AO,4AY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group Conforming</td>
<td>3SO,3LY,4SO,4LY,4AO,4AY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Handwriting Speed</td>
<td>3SO,3LY,4SO,4AO,4AY</td>
<td></td>
<td>4SO</td>
</tr>
<tr>
<td>Psychomotor Abilities:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jump and Reach</td>
<td>3SO,3LY,4SO,4LY,4AO,4AY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wall Pass</td>
<td>3SO,3LY,4SO,4AO,4AY</td>
<td></td>
<td>4SO</td>
</tr>
<tr>
<td>Shuttle Run</td>
<td>3SO,3LY,4SO,4AO,4AY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measure</td>
<td>Not significantly different from ACC group</td>
<td>Significantly lower than ACC group</td>
<td>Significantly higher than ACC group</td>
</tr>
<tr>
<td>-------------------------------------------</td>
<td>-------------------------------------------</td>
<td>-----------------------------------</td>
<td>-----------------------------------</td>
</tr>
<tr>
<td><strong>March 1961 measures (cont.)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teacher Rating Scale:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total first 12 items</td>
<td>3S0,3SY,4S0,4SY</td>
<td>4A0,4AY</td>
<td></td>
</tr>
<tr>
<td>Emotional Adjustment</td>
<td>3S0,3SY,4S0,4SY,4A0,4AY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Social Adjustment</td>
<td>3S0,3SY,4S0,4SY,4A0,4AY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical Coordination</td>
<td>3S0,3SY,4S0,4SY,4A0,4AY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Creative Thinking Tests:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Object Uses--Fluency</td>
<td>3S0,3SY,4SY,4AY</td>
<td>4A0</td>
<td>450</td>
</tr>
<tr>
<td>Word Uses--Fluency</td>
<td>3S0,3SY,4S0,4A0,4AY</td>
<td></td>
<td>450</td>
</tr>
<tr>
<td>Word Uses--Flexibility</td>
<td>3S0,3SY,4S0,4SY,4A0,4AY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plot Titles--Cleverness</td>
<td>3S0,4S0</td>
<td>3S0,4S0,4A0,4AY</td>
<td></td>
</tr>
<tr>
<td>Expressional Fluency</td>
<td>3S0,3SY,4S0,4SY</td>
<td>4A0,4AY</td>
<td></td>
</tr>
<tr>
<td>Plot Questions Sensitivity</td>
<td>4SY</td>
<td>3S0,3SY,4A0,4AY</td>
<td>450</td>
</tr>
<tr>
<td>Object Improvement</td>
<td>3S0,3SY,4S0,4SY,4A0</td>
<td>4A0</td>
<td></td>
</tr>
</tbody>
</table>

TABLE 2

Summary of Differences Between Accelerated Girls and Girls in the Six Comparison Groups on 11 Measures Where the Interaction Was Significant

<table>
<thead>
<tr>
<th>Measure</th>
<th>Not significantly different from ACC girls</th>
<th>Significantly lower than ACC girls</th>
<th>Significantly higher than ACC girls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metropolitan Achievement Test-Intermediate Battery:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Battery Score</td>
<td>4SY</td>
<td>3S0,3SY,4A0,4AY</td>
<td>4SO</td>
</tr>
<tr>
<td>Word Knowledge</td>
<td>3S0,3SY,4SY</td>
<td>4A0,4AY</td>
<td>4SO</td>
</tr>
<tr>
<td>Reading</td>
<td>4SO,4SY</td>
<td>3SO,3SY,4A0,4AY</td>
<td>4SO</td>
</tr>
<tr>
<td>Spelling</td>
<td>3SY,4SO,4SY,4A0</td>
<td>3SO,4AY</td>
<td>4SO</td>
</tr>
<tr>
<td>Language Total</td>
<td>3SO,3SY,4SO,4SY,4A0</td>
<td>3SO,4AY</td>
<td>4SO</td>
</tr>
<tr>
<td>Language Study Skills</td>
<td>3SO,4SO,4SY,4A0,4AY</td>
<td>3SY</td>
<td></td>
</tr>
<tr>
<td>Social Studies Study Skills</td>
<td>3SO,4SO,4SY,4AY</td>
<td>3SY,4A0</td>
<td></td>
</tr>
<tr>
<td>Handwriting Legibility</td>
<td>3SO,3SY,4SO,4SY,4AY</td>
<td>3SY,4A0</td>
<td>4A0</td>
</tr>
<tr>
<td>Psychomotor Abilities:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basketball Throw</td>
<td>3SO,3SY,4SO,4SY,4A0,4AY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sociometric Instrument</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Creative Thinking Tests:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sentence Improvement</td>
<td>3SO,3SY,4SO,4SY,4A0,4AY</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Measure</th>
<th>Not significantly different from ACC boys</th>
<th>Significantly lower than ACC boys</th>
<th>Significantly higher than ACC boys</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metropolitan Achievement Test--</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intermediate Battery:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Battery Schore</td>
<td>350,3SY,4SY</td>
<td>4AO,4AY</td>
<td>4SO</td>
</tr>
<tr>
<td>Word Knowledge</td>
<td>350,3SY,4SY</td>
<td>4AO,4AY</td>
<td>4SO</td>
</tr>
<tr>
<td>Reading</td>
<td>350,3SY,4SY</td>
<td>4AO,4AY</td>
<td>4SO</td>
</tr>
<tr>
<td>Spelling</td>
<td>350,3SY,4SO,4SY,4AY</td>
<td>4AO</td>
<td>4SO</td>
</tr>
<tr>
<td>Language Total</td>
<td>350,3SY,4SY</td>
<td>4AO,4AY</td>
<td>4SO</td>
</tr>
<tr>
<td>Language Study Skills</td>
<td>350,3SY,4SO,4SY</td>
<td>4AO,4AY</td>
<td>4SO</td>
</tr>
<tr>
<td>Social Studies Study Skills</td>
<td>350,3SY,4SO,4SY</td>
<td>4AO,4AY</td>
<td>4SO</td>
</tr>
<tr>
<td>Handwriting Legibility</td>
<td>350,3SY,4SO,4SY,4AO,4AY</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Psychomotor Abilities:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basketball Throw</td>
<td>350,3SY,4SY,4AO,4AY</td>
<td></td>
<td>4SO</td>
</tr>
<tr>
<td>Sociometric Instrument</td>
<td>35S,4SY,4AO,4AY</td>
<td></td>
<td>350,4SO</td>
</tr>
<tr>
<td>Creative Thinking Tests:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sentence Improvement</td>
<td>350,3SY,4SY,4AO,4AY</td>
<td></td>
<td>4SO</td>
</tr>
</tbody>
</table>

younger fourth graders of average learning abilities (4AO and 4AY). 9

From this study Klausmeier and Ripple conclude that the results of accelerating pupils by skipping a grade are not harmful.

Since the accelerates performed as well or better than their older third grade controls at that time, their acceleration was not harmful....To the extent that enabling students of superior learning abilities to graduate from high school at age 17 rather than age 18 is a worthwhile end, the results of this experiment are interpreted as strongly favorable toward accelerating older second graders of superior learning abilities to the fourth grade following a 5-week summer session. 10

A year after the first study was conducted, a follow-up study was made. Its purpose also was to determine the effects of the acceleration. This time the Acc group was compared to four groups of fifth graders, none of which had been accelerated. Essentially the same battery of tests were given. The results were analyzed and then tabulated in a table similar to Tables 1, 2, and 3. In summary of this follow-up study Klausmeier wrote:

In summary, toward the end of the fifth grade and the second year after acceleration, the accelerated pupils were equal to or surpassed the nonaccelerated pupils of average abilities and the younger pupils of superior abilities in all measures of intellectual and psychomotor abilities and adjustment; also, the accelerated pupils were significantly lower than non-

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9 Ibid., pp. 98-99.
10 Ibid., pp. 99-100.
accelerated older bright pupils only in Word Knowledge, Language Total, and Handwriting Legibility.

Four years later, when the accelerates were near the end of the ninth grade, a second follow-up study was made. Again the accelerated group was compared to four other ninth grade groups by means of a battery of tests, though different than the ones used in the first two studies. In addition, a questionnaire on participation in school activities and special programs was given to each student. Without reproducing any of the tables included in this second follow-up study, the conclusion drawn by the authors was:

Based upon all the data collected toward the end of the ninth grade, the effects of acceleration are considered completely desirable. Some bright older children should be accelerated during the elementary school years so that they become the younger high achieving members of their classes rather than remaining the older members throughout their school life. One can predict with confidence that they will continue to be high achievers and to participate in many school activities throughout their high school years.

---


We will conclude our look at studies in education with a description of an experiment done almost twenty years ago in the Minneapolis and St. Paul public schools. In describing this study an outline format will be used consisting of five sections: purpose, assumptions, hypotheses, procedure, results.

**Purpose**

The purpose of the study was to gain a better understanding of the teacher's role in the classroom, and how to utilize this knowledge in controlling classroom behavior. Also, it is hoped that certain principles of teaching can be established which can guide a teacher who wishes to control his own behavior. As Flanders says:

> The first step toward systematic classroom management is made when a teacher understands how to control his verbal communication so that he can use his influence as a social force.\(^{13}\)

**Assumptions**

Certain assumptions were made in the analysis of teacher influence. These are:

---

1. The verbal behavior of the teacher is an adequate sample of his total behavior.
2. What teachers say determines to a large extent the reactions of students. The teacher is an influential authority figure.
3. Teachers can control their verbal participation in the classroom.

Hypotheses

Three hypotheses were proposed which, it was hoped, would contribute to a theory of instruction. These hypotheses must be cause-and-effect statements which, if verified empirically, could become principles of instruction "that a teacher can then use to predict the consequences of his own behavior under certain conditions."\(^\text{14}\)

The hypotheses are:

Hypothesis One: Indirect teacher influence increases learning when a student's perception of the goal is confused and ambiguous.
Hypothesis Two: Direct teacher influence increases learning when a student's perception of the goal is clear and acceptable.
Hypothesis Three: Direct teacher influence decreases learning when a student's perception of the goal is ambiguous.\(^\text{15}\)

Procedures

The purpose of the experiment is to test the above hypotheses to see if they hold up in classroom situations. The hypotheses are predictions of student achievement as related to teacher behavior.

\(^\text{14}\)Ibid., pp. 111-12.

\(^\text{15}\)Ibid., p. 16.
The teacher's behavior serves as the independent variable and student achievement as the dependent variable. The teacher's behavior to be measured is his spontaneous verbal communication. This was done by a system called interactional analysis. Student achievement and attitudes were measured by achievement tests given before and after a two-week unit of study, and by student-attitude inventories. The measures of the student's attitudes and academic achievement are correlated with the verbal patterns of the teacher in the analysis of the results.

Interactional analysis is a technique of quantifying verbal communication to measure teacher influence. It involves the classification of the teacher's verbal behavior every three seconds by means of a set of categories. The ten categories used in the analysis are given in Table 4. The observer-recorder sits in the classroom and every three seconds records the appropriate behavior during that interval. Those teachers who have a larger number of actions falling into categories one through four are said to have an indirect influence on their students. This gives rise to greater freedom of action for their students. Teachers with a larger number of actions falling into categories five through seven are said to exert a direct influence on their students. This gives rise to less freedom of action for their students. Direct influence usually denotes more teacher participation (or dominance) and tends to establish restraints on student behavior.

The field study involved selecting fifteen social studies teachers and sixteen mathematics teachers at the junior high level. Each was asked to teach an appropriate two-week study unit that was
| TABLE 4 |
| Categories for Interaction Analysis, 1959 |

<table>
<thead>
<tr>
<th>TEACHER TALK</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Indirect Influence</strong></td>
<td></td>
</tr>
<tr>
<td>1. ACCEPTS FEELING: accepts and clarifies the tone of feeling of the students in an unthreatening manner. Feelings may be positive or negative. Predicting or recalling feelings are included.</td>
<td></td>
</tr>
<tr>
<td>2. PRAISES OR ENCOURAGES: praises or encourages students' action or behavior. Jokes that release tension, but not at the expense of another individual, nodding head or saying &quot;um hum?&quot; or &quot;go on&quot; are included.</td>
<td></td>
</tr>
<tr>
<td>3. ACCEPTS OR USES IDEAS OF STUDENT: clarifying, building, or developing ideas suggested by a student. As teacher brings more of his own ideas into play, shift to category 5.</td>
<td></td>
</tr>
<tr>
<td>4. ASKS QUESTIONS: asking a question about content or procedure with the intent that a student answer.</td>
<td></td>
</tr>
</tbody>
</table>

| **Direct Influence** | |
| 5. LECTURING: giving facts or opinions about content, or procedure; expressing his own ideas, asking rhetorical questions. |
| 6. GIVING DIRECTIONS: directions, commands, or orders which students are expected to comply with. |
| 7. CRITICIZING OR JUSTIFYING AUTHORITY: statements intended to change student behavior from unacceptable to acceptable pattern; bawling someone out; stating why the teacher is doing what he is doing; extreme self-reference |

<table>
<thead>
<tr>
<th>STUDENT TALK</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>8. STUDENT TALK-RESPONSE: talk by students in response to teacher. Teacher initiates the contact or solicits student statement.</td>
<td></td>
</tr>
<tr>
<td>9. STUDENT TALK-INITIATION: talk initiated by students. If &quot;calling on&quot; student is only to indicate who may talk next, observer must decide whether student wanted to talk.</td>
<td></td>
</tr>
</tbody>
</table>

| SILENCE | |
| 10. SILENCE OR CONFUSION: pauses, short periods of silence and periods of confusion in which communication cannot be understood by the observer. |

constructed in their area of expertise. Approximately half of the teachers were chosen whose teaching style was characterized by a tendency towards "direct influence" and the other half selected because their teaching style was characterized by a greater tendency towards 'indirect influence.' The three observers were assigned a schedule that would permit them to perform the analysis of teacher influence. Reliability among the observers was a crucial condition to control the independent variable. As Flanders said:

> The problem of observer training is twofold: first, converting men into machines, and second, keeping them in that condition while they are observing. The ideal observer team is a group of likeminded individuals who will respond consistently with the same category number when presented with the same communication events.\(^{16}\)

**Results**

Teachers with a tendency to teach in an indirect way were isolated through the technique of interactional analysis. The students of these teachers showed greater academic achievement than did the students of those teachers who favored a more direct teaching method. In fact, as the influence pattern of the teacher approached a more consistently direct or indirect pattern, the differences in achievement became larger.

The main hypotheses of this study are supported by evidence that student achievement and attitudes scores were significantly higher for those classes in which the teachers were more indirect, and that variation of teacher influence during the 2-week units of study

\(^{16}\textit{Ibid.}, p. 23.\)
followed the theory and hypotheses described in Chapter I in those classes with superior achievement.17

For example, it makes sense that during the beginning of the two-week unit learning goals are somewhat ambiguous. The indirect teachers allowed students to express their own opinions and to feel their way along during this initial period. This is contrary to what most teachers would do. However, achievement scores support Hypothesis 1. Likewise, as the unit progressed, and goals became clear, the indirect teachers became more direct in their methods. This is in agreement with Hypothesis 2, and the achievement scores indicate that more learning did take place.

The indirect teachers tended to be more flexible in their behavior, easily switching from indirect to more direct methods as the class moved from initial planning activities to more evaluative type activities. This element of flexibility seems important for increasing pupil learning.

17Ibid., p. 94.
Before the scientific revolution of the sixteenth and seventeenth centuries, there were two worlds: the earth and the heavens. Outside of religious thought, there was no bridge between them. The laws that applied to one did not work in the other. There was a split. Two worlds. Two truths.

The scientific revolution bridged this rift and showed that the same laws apply to both worlds. It brought them together. That was the Newtonian synthesis. But in so doing, it created a rift between two new worlds: the outer, objective world of nature and the inner, subjective world of man. The objective world of atoms and stars could be comprehended by the laws of science. The subjective world of man was one of life, love, and death, and was incomprehensible within the framework of the laws of science. Again, there were two worlds. Two truths.

This is the tragedy of modern mind which "solved the riddle of the universe," but only to replace it by another riddle: the riddle of itself.¹

¹Koyre, op. cit., p. 24.
Some contend that science again can bridge the gap and bring the two worlds together. These people would say that the laws of science, which are applicable to the world outside of man, are also applicable to man himself. All of nature can be encompassed within the laws of science. In such an attempt man himself becomes the object of scientific analysis, and through the methods of science—with the help of a Newton or two—the two worlds again become as one.

This is the quest of many social scientists: to find the laws of human behavior and, thus, give a firm scientific basis to the study of man. This is the aim of the three studies in education that were described in Chapter III. In each of the studies the investigators want to establish causal relationships that are confirmable by experiment. Their goal is to discover laws of teaching and learning that would contribute toward the establishment of a science of education. It is towards this attempt that we must now address ourselves. The manner in which this will be done is to analyze the three studies with respect to the list of characteristics common to science that were arrived at in Chapter 2.

Most of man's time is spent obtaining the necessities of life. There is always, though, some time left over for leisure, for contemplation. It is this time for contemplation that the Nobel Price laureate, Erwin Schrodinger, refers to as the "play" of man.² It is

in this playtime that the arts have their beginning. It is also during
this playtime that science begins.

Man seeks to understand nature. He brings his total self to bear
on a problem. Through experimentation and/or observation, interwoven
with philosophical speculation, he discovers certain patterns displayed
in nature. These patterns reduce diversity to simplicity, chaos to
order. Because such wide realms of experience can be reduced to simple
representation, these patterns, or laws, possess an element of
elegance or beauty, about them.

...the reduction of a colorful variety of phenomena
to a general and simple principle, or, as the Greeks
would have put it, the reduction of the many to the
one, is precisely what we mean by 'understanding.'3

Explanation of these patterns are then offered which can lead to the
prediction of new phenomena verifiable by further experimentation and/or
observation. The discovery of these patterns, and the explanation,
or theory, that accounts for them, are acts of the creative mind.
Many times the creative act forces a shift in man's way of thinking
and causes him to view the world in a new way. Though these paradigm
shifts are characteristic of science in general, they could not be
typical of every scientific study. Finally, the community of scholars
that shares an interest in the particular realm of phenomena under
investigation must eventually reach a consensus of opinion regarding the
patterns and their explanations.

3Werner Heisenberg, Physics and Beyond (New York: Harper and
The essential attributes, then, that are both basic and common to the scientific endeavor can be summarized as follows:

1. Grounded on experimentation and/or observation
2. Existence of, or search for, patterns that possess an inherent beauty
3. Explanations of the patterns
4. Consensus
5. Paradigm shifts

In comparing the three studies to these five characteristics we can begin by saying that all three studies meet the criterion of being based on experimentation and/or observation. In all three studies investigators went into schools and attempted to verify certain hypotheses. Observations were made and instruments were used to procure quantitative data. Though it is agreed that these studies are experimental, one is immediately confronted with important differences between these studies and a typical experiment in the natural sciences. To serve as an example of a typical experiment in the natural sciences we intentionally choose a very simple one. A more difficult experiment would only require more description. Conceptually and methodologically, it would be similar.

The problem is to measure the cross-sectional area of an antenna wire. Not only is the term "cross-sectional area" well defined, but the copper wire itself is well defined with respect to its characteristic properties (density, specific heat, elasticity, etc.).
The instrument used to make the measurement, a micrometer, is a simple, mechanical device whose mode of operation any scientist would understand and agree on. Once the micrometer measures the diameter of the wire, its cross-sectional area can readily be computed. Within the stated limits of uncertainty of the measurement the results are perfectly valid and reliable.

The situation differs considerably when we look at one of the educational experiments. For example, Flanders wants to verify his hypothesis that indirect teaching increases learning when a student's perception of the goal is unclear. To begin with, the concept "indirectness" is ambiguous and poorly defined. How can one measure such an obscure concept? Flanders himself seems to realize the difficulty in quantifying such a concept as this. He writes:

It is possible that category systems are not yet well enough established to propose a single way to measure this feature of teaching behavior. Also, the conventions with regard to classifying verbal statements differ, one research team compared with another, and pushing toward a single operational definition may increase error in making comparisons between different studies rather than increasing the precision of our knowledge.4

Not only is the concept ambiguous, but there is no agreement on the instrument used to measure it. Many of the terms used to describe the categories for interactional analysis are also ambiguous. What one observer sees as criticism of students by a teacher, another

observer might interpret quite differently. Little wonder, then, that
the results of such a measurement have questionable validity or reli-
ability.

Experimentation in the social sciences is far more difficult
than in the natural sciences due to the complexity of the subjects
under study: human beings. Far more variables enter into experi-
mental work with humans than with inanimate objects or with laboratory
animals. The difficulties and inaccuracies of the measurements
involved increase accordingly. Rosenthal found this out as he moved
from rat mazes into schoolrooms. It begins to seem that the deter-
mination of the cross-sectional area of a wire is a measurement of a
different kind rather than one of a different degree. We conclude
that in education, as in the natural sciences, patterns are searched
for in an objective manner, and, therefore, experimentation does go on.
But it requires more than experimentation to make a science.

We now turn to an analysis of the three studies with respect to
the other four characteristics of science. We begin by considering
the Pygmalion effect.

The Pygmalion Effect

Rosenthal's study of self-fulfilling prophecies within the class-
room is an experiment done to confirm a hypothesis. In this sense
it is similar to Galileo's gedanken experiment that was described in
Chapter II. Galileo had an idea as to how an object should move on
a horizontal, frictionless surface and devised his experimental
apparatus to test this idea. Likewise, Rosenthal has an idea that if a teacher expects his students to do well in school, then they will do so. If this hypothesis is confirmed by experimental findings, and if it is repeated and confirmed by other investigators to the point where there is general consensus regarding the validity of the findings, then the hypothesis reaches the status of a law. Rosenthal is seeking a principle that would guide teachers in their work and would enhance learning. The law seems to be of such generality that it exceeds the boundaries of the teacher-pupil relationship. It says that if you treat people decently as human beings, and expect them to live up to their potential, then your expectations will be met. It seems to say something about human nature. Because of its generality and because it attempts to bring order into man's world, the idea has an element of beauty to it.

But does the idea work? That is the pragmatic criterion for truth in science. Rosenthal, of course, says it does. His answer is based on his experimental findings. Figure 5 shows that, at least for grades one and two, the children in the experimental group gained twice as much in I.Q. points as did the control group. Other investigators, though, disagree. Robert Thorndike in a review of *Pygmalion in the Classroom* finds inadequacies in the data gathering and in the data analysis. He says of some of the pretest data, "if these pretest data show anything, they show that the testing was
utterly worthless and meaningless.” He concludes his review as follows:

...indications are that the basic data upon which this structure has been raised are so untrustworthy that any conclusions based upon them must be suspect. The conclusions may be correct, but if so it must be considered a fortunate coincidence.

We are back to the difference between experimentation in education and experimentation in the natural sciences. The instruments Rosenthal used to obtain his data were the Flanagan Tests of General Ability. An I.Q. test is a far more complicated instrument than a micrometer. Also, the concept being measured, human intelligence, is a far more complicated concept than the cross-sectional area of a copper wire. And finally, the object being measured, a human being, is a far more complicated entity than a wire. Other investigators have tried similar experiments and have obtained results that vary from support of Rosenthal's thesis to almost total refutation of it. It is almost as though the investigator can obtain whatever results he wishes. Most studies do indicate that there is some validity to the idea of self-fulfilling prophecies. But there are always qualifications. The point here is that the study lacks consensus. One methodological problem that contributes to this lack of consensus is the control of variables. In human experimentation how

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6 Ibid., p. 711.
does one study a particular aspect of behavior while keeping all other variables constant? Dunkin and Biddle refer to this problem in their summary of studies that were stimulated by the publication of the Rosenthal experiment.

...However, there is no experimental confirmation of any of the above findings. The shortage of experimental studies involving these variables of teacher behavior is worthy of comment, since it probably indicates the great difficulty of experimentally manipulating a single variable of teacher behavior without also changing other teacher behaviors and so confounding the interpretation of results.7

Thorndike says the Pygmalion effect "may be correct." But without consensus it can hardly be pronounced a law. Laws of science demand consensus. One might argue that consensus will be reached one day. What we need are more investigators running tighter experiments which will confirm the hypothesis. This may be true. Certainly the history of science illustrates many crucial experiments whose results were not immediately accepted. It took several generations before most men accepted the Copernican thesis. Usually profound, innovative ideas take time to permeate the thick skin of common sense. We see the world from a certain perspective, and to look upon it differently requires a gestation period. What we can say is that at this point in time there is not general consensus among educators about Rosenthal's hypothesis.

We now ask if the Rosenthal study involves theory, i.e., is there any explanation of the experimental results? Whereas a few explanations were given to account for the results, they were offered more in the way of hypotheses than in terms of a coherent theory. A theory should not only explain the results of the specific experiment but should predict new phenomena that can be verified by further experimentation/observation. Though Rosenthal's explanations might be said to possess some predictive value, he failed to check up on his explanations by utilizing actual classroom observations. This was pointed out by Dunkin and Biddle.

...Rosenthal and Jacobson failed to observe classroom behavior and thus failed to discover the process by which teachers might have translated their expectations into differential treatment of pupils.\(^8\)

Thus, although explanations were offered for the experimental findings, an inclusive theory which would account for the results and also explain related phenomena was not proposed.

We have listed paradigm shifts as one of the characteristics of science. Indeed, for any major field of science such shifts do occur given sufficient intervals of time. However, such upheavals are not characteristic of each and every study in science. The vast majority of studies are part of normal science where accumulation occurs through puzzle and problem-solving and through articulation. Only once in a great while does a study uncover an anomaly whose solution results in a paradigm shift. Throughout the history of

\(^8\text{Ibid.}, \text{p. 129.}\)
science only a small percentage of all the studies done have caused revolutions in physical and philosophical thought. An investigation of the crystal lattice structure of arsenic sulfide could contribute to our understanding of solid state physics, yet hardly cause a shift in the way man views the world. The point here is that paradigm shifts are characteristic of science, but not of specific studies in science. Therefore, we cannot use this characteristic to analyze the three studies in education. But since these shifts are characteristic of science we can ask if the field of education itself shows such shifts.

In a sense one could well argue that there have been revolutions in education which produced profound changes in the way man views the world. For example, the vision of Thomas Jefferson and Horace Mann that the common man is entitled to a free education at the expense of the state was a profound idea that has shaped the character of this nation. One might even argue that the progressive movement in education with its emphasis on the child-centered curriculum forced a change in the way in which educators viewed the educational process. Granted that these examples show that new ways of looking at the world do occur in education, nevertheless, they are not examples of paradigm shifts in the sense that Kuhn uses that term. For Kuhn in order to have a paradigm shift there must exist an established and accepted paradigm. This means that all the practitioners in a given field agree upon the principles and methods that govern their arena of
interest. It is in this sense that the term is used in this paper.

...Men whose research is based on shared paradigms are committed to the same rules and standards for scientific practice. That commitment and the apparent consensus it produces are prerequisites for normal science, i.e., for the genesis and continuation of a particular research tradition. Acquisition of a paradigm and of the more esoteric type of research it permits is a sign of maturity in the development of any given scientific field.9

Education lacks such shared paradigms. There is no consensus among educators as to how one goes about solving any given problem, no commitment "to the same rules and standards." The vast majority of practitioners in education are the classroom teachers and they are far too busy teaching to worry about the establishment of paradigms. It is within the colleges of education that one hears of a science of education, and if a paradigm exists within these schools, it is the model of quantitative research. Yet not all of the professors adhere to that model. Without a shared paradigm how can there be a paradigm shift?

All physicists share a common paradigm. There is only one way to do high energy physics, one school of thought. In psychology there are various schools of thought and this reflects the weakness of the philosophical underpinnings of that subject. In education it seems that each person has his own ideas about teaching and learning. Little wonder that one encounters so many philosophies of education,

9Kuhn, op. cit., p. 11.
many of them at odds with one another. As Harry Broudy has put it:

...what sort of scientific enterprise is it in which so many different theories continue to flourish side by side, seemingly invulnerable to refutation by argument or test?10

Effects of Accelerating Bright Older Pupils from Second to Fourth Grade

Klausmeier believes that bright, older pupils in a given grade should be permitted to skip a grade level during their elementary schooling.

...To keep an older bright child throughout his school life with younger, less mature children keeps him out of a productive career for at least 1 year, and it may reduce his learning efficiency and motivation for learning.11

The purpose of the study is to determine the effects of allowing pupils to skip one grade. This is reminiscent of studies in applied medical research where a group of people are given an experimental drug to determine the effects of the drug. In such research a relation is being sought. Is one found in the Klausmeier study?

The results indicate that the experimental group consistently scored as well, if not better, on all the tests as did any of the other groups except the 4S0 group. This result was reached by an analysis of the test scores which led to the construction of Tables 1,


2, and 3. We have spoken of how the laws of science are characterized by a sense of aesthetics. The American theoretical physicist, Richard Feynman, has stated this view quite succinctly: "You can recognize truth by its beauty and simplicity." There is no beauty or simplicity to the tables in Chapter IIII. This is true of all quantitative research in education. There is simply no beauty in a monograph of educational statistics. We conclude that whereas a relation between accelerating pupils and their continued ability to score well on tests might possibly have been established, certainly we cannot refer to this relation as a law.

Also, there is no consensus among educators about these results. The fact that permitting bright, older children to skip a grade level is not a common practice attests to this lack of consensus. Even if the accelerated students do continue to achieve at a high level as determined by test scores, this is no basis for concluding that, "the effects of acceleration are considered completely desirable." What about social and emotional ramifications of the acceleration? What emotional side effects occur when a seven year old child is removed from his classmates and put into another class where most of the students are older than he is and are strangers to him? The type of follow-up tests done by Klausmeier cannot measure these effects.

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12 Feynman, op. cit., p. 17.

13 Klausmeier, Vol. 59, No. 1, p. 58.
Yet these types of effects are just as important, if not more so, than the effects that the follow-up studies do try to measure. Again we are reminded of applied medical research and the unknown effects of drugs over extended periods of time. Ellul warns us:

Man can never foresee the totality of consequences of a given technical action. History shows that every technical application from its beginnings presents certain unforeseeable secondary effects which are much more disastrous than the lack of the technique would have been. These effects exist alongside those effects which were foreseen and expected and which represent something valuable and positive.14

Finally, no explanations are offered to account for the results. The investigators should have been especially concerned about the difference between the control group, 3S0, and the experimental group, ACC, since both groups were of the relative age and ability. For example, why was the experimental group significantly higher than the control group on four measures? Why were the control group boys higher than the accelerated boys on the Sociometric instrument? The point is that not only were these questions unanswered, they were unasked.

**Teacher Influence, Pupil Attitudes and Achievement**

The purpose of this experiment is to seek both understanding and control of the way in which teachers influence students. Science

implies efficiency and control. These two factors are of immense importance in our technocratic, bureaucratic society. Just as an astronautical engineer looks for efficiency and control in the design of an ion propulsion system, so a school administrator looks for efficiency and control in the design of an educational system, be it a school or a set of instructional materials. Science implies law and order and with a rocket ship that is what we want. But do we want law and order within a second grade classroom?

...That men are in some sense machines and that they are in a more important sense not machines are both the declarations of mind. To yearn for a science that would give us perfect control of learning and to reject its use for that purpose, if it were found, is quite the human thing to do.15

Studies in education do seem to be characterized by this search for control. Such is not always the case, though, in the natural sciences. To return to an example at the beginning of Chapter II, Bethe wanted to know why the stars shine. He was not concerned as to how this knowledge might be put to human use. The lonely astronomer photographing distant galaxies atop his mountain observatory has no interest in the application of his work to human problems. He is pursuing knowledge for knowledge sake in the sense of the quote from Poincare mentioned in Chapter II. On the other hand, the cytologist studying cancer in laboratory animals is obviously interested in not only understanding the nature of cancer cells but, also, in putting

this knowledge to use for the benefit of mankind. Here we have the difference between pure and applied science. The historical studies cited in Chapter II all leaned toward the pure aspect of science. Due to a change in the sociology of science since the scientific revolution, especially during the last one hundred years, scientific research has become more and more applied. Ellul writes, "Science is becoming more and more subordinate to the search for technical application."

One reason for this is the tremendous financial support given by the state to scientific research. The scale of the intended applications usually tends to be such that the result tends to be technology. Technology is the application of scientific principles to human problems on a grand scale. It is into this arena that research in education seems to fall. Ellul warns us of the pitfall that awaits education if it opts for this paradigm of scientific research.

...education will no longer be an unpredictable and exciting adventure in human enlightenment, but an exercise in conformity and an apprenticeship to whatever gadgetry is useful in a technical world.17

The Flanders' study is an effort to establish principles of instruction that will lead to greater control for the teacher in a classroom. This is done by advancing three hypotheses and then attempting to verify them experimentally. If the hypotheses can be verified, they will become principles of instruction. The results of the study

16Ellul, op. cit., p. 312.

17Ibid., p. 349.
support the above thesis. Thus, Flanders believes that he has formulated some principles of instruction. But, as with the study by Klausmeier, we find nothing aesthetically pleasing about Flanders' results. The same problems present themselves: too many variables, too much ambiguity in the concepts, and lack of a "reduction of the many to the one." Flanders, himself, realizes the problems in methodology inherent in such a study (see p. 89). Also, there is a total lack of consensus concerning the results. Dunkin and Biddle reviewed many field studies and experimental studies that dealt with the concept of "indirectness." They concluded:

...findings from field surveys appear to show relationship between indirectness and pupil growth, although the evidence is weak, contradictory, and the relations may be curvilinear or contextually bound. However, evidence from experiments is equivocal, suggesting that the apparent relationships found in field surveys are not causative. Thus, the case for "indirectness" is not demonstrated.

In fact the studies are in such a state of disarray that Dunkin and Biddle are in favor of abandoning the concept altogether.

..."indirectness" is simply not a unitary phenomenon at all...Our conclusion, then, is that teachers should cease to use it in conceptualizing their classroom performances in the future.

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18 Heisenberg, op. cit., p. 33.
19 Dunkin, op. cit., p. 132.
20 Ibid., p. 364.
Any classroom teacher could tell that something was amiss with the hypotheses. When students are confused and do not have a clear perception of what they are supposed to do, then that is the time to give them explicit directions, not let them grope their way along. This was one of the problems with the "discovery" method that was built into many of the national curriculum projects in science a decade ago. A twelfth grade physics class is not composed of so many Gilileos and Newtons. They are just students who need help and directions.

No explanations are given to account for the results. Because the hypotheses refute common sense, surely some form of explanation is demanded. For example, why should direct teacher influence decrease learning when a student's perception of the goal is ambiguous? Again, as with the Klausmeier study, not only do questions remain unanswered, they remain unasked.

**Summary of Results**

Table 5 is an effort to summarize the results of this chapter. Across the top of the table are the five characteristics that were used in the analysis. Arranged down the left-hand side of the table are: (1) a typical field of natural science, astronomy, and the field of education; (2) four studies that purport to be scientific, one taken from astronomy and the three from education that we have analyzed.

In part (1) of the table it is seen that the field of astronomy satisfies all of the characteristics of the scientific endeavor.
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<td>no</td>
<td>yes</td>
<td>no</td>
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</tr>
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<td></td>
<td></td>
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<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Pygmalion Effect</td>
<td>yes</td>
<td>?</td>
<td>yes (weak)</td>
<td>no</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Effects of Accelerating Pupils</td>
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<td>no</td>
<td>no</td>
<td>no</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Teacher Influence</td>
<td>yes</td>
<td>no</td>
<td>no</td>
<td>no</td>
<td>Not applicable</td>
</tr>
</tbody>
</table>
Astronomy is based on experimentation and/or observation. There are laws such as Hubble's Law that encompass a vast amount of observable phenomena and express that knowledge in simple, elegant forms. There are theories, theories for example which try to account for Hubble's Law. And there is general consensus about these laws and theories among the scientific community. Finally, the history of astronomy records examples of paradigm shifts such as the Copernican revolution or the more recent belief in the expanding universe.

Education in its attempt to be a science is based on experimentation and/or observation. However, no patterns have been found. There are no laws of education. What laws one might ascribe to education are actually laws borrowed from other social sciences. In this sense one could say that education is an attempt to apply certain laws of the social sciences to problems of teaching and learning. But to speak of a science of education is to speak in an odd manner, for what is its content? What are its laws? And name dressing will not help. Dewey knew that.

It is no reproach to a would-be science that in early stages it makes experiments and measurements the results of which lack generalized significance. A period of groping is inevitable. But the lack of an intellectually coherent and inclusive system is a positive warning against attributing scientific value to results merely because they are reached by means of recognized techniques borrowed from sciences already established and are capable of being stated in quantitative formulae. Quantity is not even the fundamental idea of mathematics.21

21 Dewey, op. cit., p. 27.
There are theories in education and this is as it should be. An immature science should be characterized by philosophical speculation. Dewey recognized this, too.

...The scientific content of education consists of whatever subject-matter, selected from other fields, enables the educator, whether administrator or teacher, to see and to think more clearly and deeply about whatever he is doing. Its value is not to supply objectives to him, any more than it is to supply him with ready-made rules. Education is a mode of life, of action. As an act it is wider than science. The latter, however, renders those who engage in the act more intelligent, more thoughtful, more aware of what they are about, and thus rectify and enrich in the future what they have been doing in the past.22

Just as the individual studies in education lack consensus, so do the theories in education. It seems that for every curriculum theorist there is a curriculum theory. Nor is there even agreement on the nature of the learning process, and learning theory is one of the more scientific areas in education. We have already spoken of the lack of paradigms in education. We, thus, conclude that of the five characteristics of science, education meets only two of them.

In part (II) of Table 5 a typical experiment in astronomy, the spectral classification of a given group of stars is done by observations using suitable instruments. The experiment is done to either seek a new pattern that the observer might be looking for, or to confirm an existing law. In either case the results should "fit" into a pattern. The results of the experiment will be explained within the

22 Ibid., pp. 75-76.
framework of existing theories, and there will be consensus among the astronomers regarding the experiment, the patterns, and the explanations. The only exception would be an experiment that uncovers an anomaly, and that is a rare event in normal science.

The rest of part (11) summarizes the results of the analysis of the three studies in education. As we have already explained the characteristic of paradigm change is not applicable to specific studies in science. All three studies were experimental, yet in none of them was there any general consensus with respect to the results. No explanations were given in either the Klausmeier or the Flanders study and only rather weak explanations given in the Rosenthal study. Also, no patterns emerged in either the Klausmeier or the Flanders study. In the Rosenthal study a pattern seems to emerge but at this time it must be looked upon more as a hypothesis than as a law.

Conclusions

Some have said that modern man has been forced to live in two worlds: the objective world of science and the subjective world of man. Many believe that by bringing man under the auspices of science these two worlds can become as one. We have analyzed the attempt in education to accomplish that. What we have found is that education approached as a science does not exhibit the same characteristics that the natural sciences do. It becomes questionable whether one should even talk of a science of education. Why is there this difference between the natural sciences and education? One crucial difference is
those sciences highest in the pecking order, those sciences that have become the most mathematical and abstract, are the ones that deal with inanimate objects. Biology is a borderline case. Certainly the classification of plants and animals according to some taxonomic scheme does not constitute a science. Aristotle was capable of that. A science must be based on a minimum of broad, unifying generalizations that have both explanatory and predictive value such as the electrodynamic equations of Clerk Maxwell or the relativistic field theory of Einstein. There is great beauty in such equations. There is no beauty in a book of educational statistics. Biology has very few of these sweeping generalizations and must resort to the laws of physics and chemistry. The foundations of psychology are even weaker as is reflected in the fact that there exists various schools of thought as to how to do psychology. As a discipline comes closer and closer to the study of man the scientific hierarchy of that discipline becomes less and less.

Man is not a suitable object for scientific study, his subjective nature denies it. His inherent irrationality defies the constraints of the scientist, and his instinctive urge for freedom makes the efforts of predicting human behavior a farce. Here, then, is the problem with those disciplines such as the social sciences which would confine man and make him an object for scientific investigation. To objectify man you must turn him into a non-thinking, non-feeling entity and by so doing you annihilate man. For the very things you have destroyed are the essential attributes that make man what he is. You cannot eliminate
the irrational strain in man, nor can you confine his freedom entirely. Dostoyevsky said that man will go to any limit to retain his freedom, even to the point of going voluntarily insane. In Ken Kesey's popular book *One Flew Over the Cuckoo's Nest* that is precisely what McMurphy did when Big Nurse pushed him to the limit.

This is in no way to say that the social sciences cannot be objective in their search for truth. But it does demand the use of the concept of limits. After all, the objective search for truth does not define science. Nor is objectivity the only road to truth. We must rid ourselves of the notion that in order to seek truth we must be scientific, or even objective. Again Feynman captures it concisely, "A very great deal more truth can become known than can be proved."23 Our historical legacy documents this statement. Though the laws of science might govern our existence, they are hardly the truths that we live by.

The delightful aspect about an area such as education is just that it is so subjective. There are no equations, no unifying principles, no theories, no experiments that remain invariant under certain transformational rules. Education must be dealt with in words, with feelings, and from a human perspective. Each of us perceives the educational process from our own frame of reference and from that vantage point we confer meaning on it. The totality of this communal subjectivity must be part of the whole view of education and cannot be ignored in any objective analysis of it.

23 Ziman, *op. cit.*
We must tear the imaginary wall down that separates the world of the outside from the world of the inside. There is no difference between the world of science and the world of man. Does not man produce both art and science? Elementary particle physics is philosophy. An experimental piece of work in x-ray crystallography can be creative and beautiful, and the formulation of harmonics in the composition of a piano concerto must be scientific. Scientists have always known of this unity of experience. Kepler lived that life. So did Pascal. Bronowski writes of its influence on modern physics:

...Relativity derives essentially from the philosophic analysis which insists that there is not a fact and an observer, but a joining of the two in an observation. This is the fundamental unit of physics: the actual observation. And just this is what the principle of uncertainty showed in atomic physics: that event and observer are not separable....All the difficulties...derive from the separation between the knower and what is known. Only by joining them do we make knowledge.24

Heisenberg echoes the same thought:

...Natural science does not simply describe and explain nature; it is a part of the interplay between nature and ourselves; it describes nature as exposed to our method of questioning. This was a possibility of which Descartes could not have thought, but it makes the sharp separation between the world and the I impossible.25

It is time to close ranks. We need to come together. We need to reach out and touch one another with love, beauty, and wisdom. There is but one world: our world.


REFERENCES


Russell, James. NEA Proceedings, 1926.


Two points regarding methodology should be mentioned.

The list of characteristics common to science arrived at in Chapter Two was circulated to five faculty members at The Ohio State University. The comments of Professors Virgil Hinshaw and Ronald Laymon of the Philosophy Department and Professor Kelly Duncan of the College of Education were influential in arriving at a final choice. There was general agreement that the list was, indeed, one that the majority of scientists would concur with.

The three studies in education were chosen not only because all purported to be scientific, but, also, because they are representative studies in education. The Pygmalion Effect has been an extremely influential and controversial study and has stimulated many other similar studies. (See Dunkin and Biddle) Klausmeier is an educational psychologist well known for the "tightness" of his experimental work. The interactional analysis technique of Flanders has also stimulated many similar studies in education. Variations of his categories in analyzing teacher behavior have become common methodologies in teacher education research.