THE IMPLICATIONS OF THE RELATIVITY THEORY
FOR TEACHING SCIENCE

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CHAPTER I

ABSOLUTISM VERSUS RELATIVITY IN SCIENCE

(Historical Background for the Problem)

In the opening sentence of "The Quest for Certainty" John Dewey says, "Man who lives in a world of hazards is compelled to seek for security." Security, according to philosophic tradition, says Dewey, "...can be fulfilled in pure knowing alone."¹ That is, security is dependent upon knowing everlasting, unchanging, invariable knowledge; absolute knowledge. If this is true, the question that arises is, "Where and how shall one find absolute knowledge?"

This question is a very old one. As early as 500 B.C., the members of several different schools of thought were trying to discover by different methods and in different places the final and ultimate knowledge existing in the universe.

Idealism. One of these early schools of thought was known as idealism. Its followers—Socrates, Plato, Aristotle and others—believed that truth (absolute knowledge) exists only in the mind and can be discovered only by rationalization; by reasoning; by pure logic. The axioms, principles and conclusions of geometry are examples of such knowledge. Geometry was believed to be a world of ideal forms related to one another by universal and absolute relations, all of which exist in the mind as inborn or innate ideas and which can be discovered only by the processes of mind.

The doctrine of innate ideas was proposed by Plato. To obtain a better understanding of it, let us consider the proposition that the radii of a circle are all equal; unless they are, the circle is not perfect. Since a perfect circle cannot be drawn and does not really exist in a material sense, then it can exist only in the mind. Likewise, the ideals such as beauty, chastity, honesty, and purity were believed to exist in the mind apart from things that possess them; they were believed to be inherent possessions of mind.

The idealists believed that mind is over and above crass material things; it is the realm of the spiritual. Mind can explain material phenomena, but it cannot be explained in terms of material phenomena.

Since mind was considered superior to material things, people who dealt with material things for a livelihood were considered beneath those who dealt with ideas. Manual labor was considered menial, onerous and fit to be done only by slaves and lower classes. Physicians did not operate; that was done by barber surgeons.

Because material things continually change—something that absolute knowledge does not do—truth was believed not to exist in material things. For this reason, the idealists never doubted conclusions that were not in keeping with observations. And, since experiments deal with material things—that is, changing things—then conclusions cannot be verified by experiment. That these early Greeks never tested conclusions by experimentation
is shown by the fact that they debated generation after
generation such questions as "Why can a fish be put in a
brimming pail of water without causing the water to overflow?"

**Materialism.** The members of an opposing school, known
as materialism, believed that absolute knowledge exists in
material things; not in mind. Truth is what one tastes,
touches, smells, hears and sees; what one observes. To
find truth one should look to material things; to Nature.
Everything, even mind, can be explained in terms of material
things and physical phenomena.

The materialists confined the role of a "scientist" to
observation alone. His duty, they believed, is to get facts,
but he is definitely disqualified from making interpretation
of facts. Facts, they believed, speak for themselves. These
hard-boiled observers had no faith in knowledge discovered by
theorists and dreamers, or by communers with the supernatural.
The materialists were practical; the idealists were theoretical.

These two schools of thought existed until Greece and
Rome fell from their pinnacles and the Church, about 300 A.D.,
took over Europe. Then idealism became the hand-maid of
theology and it became holy to believe what the senses denied.

**Authoritarianism.** From the third until about the fifteenth
century, there was little independent thought in Europe. The
Pope—head of the Church—claimed to be the Vicar of Christ and
as such to exercise divine authority. His voice was the Voice
of God; his decrees were laws intended by God for the government
of men; his word on any subject, including science, was authoritative and final. All new knowledge God gave to man through the voice of the Pope or the voice of a direct representative of the Pope.

Plato's doctrine of innate ideas did not conflict with the beliefs of the Church and as a result enjoyed the sanction of holy authority. Aristotle's theory of an anthropocentric universe fitted nicely with Church doctrines because it placed the earth, and thus the Pope, at the center of the universe. Also, Aristotle's idea of finding truth by reasoning and argumentation was looked upon favorably. However, the Church demanded that all arguments be based on the writings of the Pope, of the Saints as found in the Holy Scriptures, or on those works of Aristotle which did not conflict with the beliefs of the Church.

As a result, in the Church there was founded a group who began to speculate and philosophize just as the Greek idealists had done. In the universities, all of which were dominated by the Church, the Church philosophy reigned and consequently Church practices were followed. If an observation was not in keeping with authority, belief, and tradition, it was thought necessary to prove by argument that the observation was wrong. Change and variation were explained away; they were believed to be abnormal. As a consequence, little or no progress was made in science.
However, during the period just described there were a few independent thinkers and writers. It was largely as a result of their influence that the Renaissance, which began about 1300 A. D., came about. Leonardo de Vinci (1452-1519)--painter, poet, physicist, engineer and anatomist--was one of the independents who opposed and openly attacked the dogmatism and authoritarianism of the Church and of Aristotelian thought.

Materialism Again Comes to Life. The attack really began when Copernicus (1473-1543) proposed the heliocentric theory of our solar system. This theory was substantiated by Kepler after twenty-five years of careful measurement of the movement of heavenly bodies. Galileo (1564-1642) also made observations which supported the heliocentric and contradicted the anthropocentric theory. He invented and built a telescope, and when it was turned sky-ward, it revealed the moons of Jupiter, the sunspots in motion, and the phases of Venus. Galileo also attacked Aristotelian science experimentally. The experiment with falling bodies is well known.

But, it was Descartes (1596-1650)--famous French mathematician and philosopher--who really brought materialism back into its own. He based his philosophy on the work of Copernicus, Archimedes, Galileo and others. Descartes advocated that the external world is a mechanism and that animals are machines. He says, "The animals act naturally and by springs, like a watch."2

2 Descartes, Rene, Oeuvres, IX 426, Quoted from Encyclopedia Britannica.
"...and possibly even the impressions made in the optic nerves determine our limbs to different movements, but we feel nothing of it at all, and move as if we were automata."  

Descartes believed that digestion, respiration, reproduction, and other life processes all obey physical laws, and that even the mind can be explained in terms of the chemical and physical laws of matter. Everything, except the soul of man, obeys the laws of nature.

Descartes' mechanistic and materialistic philosophy was given great impetus by Newton (1642-1727) who discovered the supposedly universal and absolute law of gravitation, and the laws of mechanics which he based upon the assumption that mass, time, space, and motion are all absolute, not relative.

Furthermore, Newton believed that matter is discontinuous; that the ultimate particles of material things do not change, and that truth can be found among material things. He says:

> It seems probably to me that God in the beginning formed matter in solid, massy, hard, impenetrable, moveable particles, of such sizes and figures, and with such other properties and in such proportion, as most conduced to the end for which He formed them; and that these primitive particles, being solids, are incomparably harder than any porous bodies compounded of them; even so very hard as never to wear or break in pieces, no ordinary power being able to divide what God Himself made one in the first creation.  

These hard, impenetrable, unbreakable particles were known as atoms.

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3 Ibid., VI 339.  
4 History of Science Society, Sir Isaac Newton, 1727-1927, p. 224.
Newton's method of research was one of analysis; the search was always for "elements." Newton invented the calculus—a method of analysis—which made it possible for him to divide mathematically time, space, mass and velocity into intervals or elements so infinitesimally small that variation within the interval or element could be neglected. The calculus has proved to be a great tool in scientific research.

With Newton, all that counted for science were phenomena that could be observed and relationships that could be formulated in mathematical terms. He said, "I do not invent hypotheses." He insisted that the phenomena to which he applied mathematics were not products of thought, but were phenomena which he observed. Newton said, "Whatever is not derived from phenomena is to be called a hypothesis and hypotheses...have no place in experimental philosophy." If all of the observed phenomena or facts are tabulated and properly arranged, facts virtually interpret themselves.

Newton's complete method of research was (1) to observe Nature, (2) to analyze and measure quantities involved, (3) to formulate the data into laws expressed in the concise language of mathematics, and (4) to use these laws to predict happenings under carefully controlled conditions. The laws he did not consider correct unless they could be proven by experiment and observation.

5 Ibid, p. 115.
*Note: From here on "experiment" includes observation.
The followers of Newton believed that he had discovered "the everlasting and invariable laws of the universe" and that his method of research was the only method. La Place envied Newton for having discovered "the" system of the world and is said to have mourned because there were no other systems to discover.

Although science was a reaction against revelation and the authoritarianism of the Church, Newton and his followers were not disbelievers in God. However, instead of believing that God expresses his will through the voice of the Pope, they believed that he expresses it through Nature. The universe they believed is one harmonious whole; a perfect mechanism made by God. In building the universe, God expressed his will; therefore, in order to know the will of God and thus find invariable, everlasting, absolute knowledge, one should look to Nature and find WHAT IS. To interpret the universe in this sense was quite easy. Alexander Pope (1688-1714) even wrote a poem based on this interpretation.

All are but parts of one stupendous whole,
Whose body nature is, and God the soul......
All Nature is but art, unknown to thee;
All chance direction, which thou canst not see;
All discord, harmony not understood;
All partial evil, universal good;
And, spite of pride in erring reason spite;
One truth is clear, whatever is, is right.

In order to increase the power of observation, make measurements more accurate, and achieve finer and finer analyses, Newton's followers invented new and better telescopes, microscopes, thermometers, analytical balances,
spectroscopes, interferometers, and other instruments. All newly discovered physical knowledge was classified, coordinated and systematized in terms of the Newtonian (classical) philosophy of science and was made to fit with the antecedent, prior, systematized physical knowledge already discovered.

In consequence of the painstaking research, many new discoveries were made; for example, the law of conservation of energy, the law of conservation of mass, the laws of thermodynamics, and the laws of electrodynamics. All of these laws were considered final and everlasting (absolutes).

In chemistry, new elements and new compounds were discovered and identified, and their chemical and physical properties were precisely and accurately determined. Because matter was considered discontinuous and atoms indestructible, the transmutation of elements was believed to be impossible.

In light, the speed of light and the wave length of each of the "elements" of the sun's bright and dark line spectra were determined; also the bright line spectrum of each of the chemical elements.

So thorough was the search that by the end of the nineteenth century, the general opinion among scientists was that everything of real consequence in physics had been discovered. Albert A. Michelson, the great American physicist, said in 1910, "The future of discovery lies only in extending the accuracy of measurement to further significant figures."[7]

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The Inadequacy of Newtonian Physics. About 1800, astronomers observed that the position of the planet Mercury was in error 42 seconds of an arc degree with the calculated position, after a period of 100 years. This discrepancy meant either an error in observation or an inadequacy of Newtonian mechanics. Because of the accuracy of observation that had been achieved in astronomy, so large a discrepancy was unlikely to be due to an error in observation. This discrepancy remained unexplained for years.

With the advent of the kinetic theory of gases in 1850, any interpretation of the universe as being completely harmonious, orderly and unchaotic was seen to be impossible. The behavior of gas molecules was found to be unpredicatable except by laws of probability. And the study of cathode rays during the latter part of the 19th century proved conclusively that there are particles of matter even smaller than an atom. These phenomena showed only minor inadequacies of classical physics.

The Michelson and Morley Experiment. In order to explain the transmission of light according to the wave theory, Huyghens postulated an ether. Also, Maxwell based his electromagnetic theory of light on the assumption that an ether exists. Both Huyghens and Maxwell believed ether is a fluid-like substance which pervades all space and permeates all matter; and since there was no evidence that the ether is in motion with respect to other parts of the universe, they assumed the ether is at rest.
In 1881, Michelson, assisted by Morley, attempted to measure the "absolute" velocity of the earth with respect to the ether. They reasoned that, if the ether is at rest, then the earth moving through it should set up ether currents just as a moving train sets up air currents.

To determine the velocity of the earth relative to the ether, they timed the passage of light a certain distance up the ether stream and back, and the same distance across the stream and back, and found the time in each case to be the same. If an ether current exists, the time for light to pass up the stream and back should be greater than the time across the stream and back, for the same reason that it takes a swimmer greater time to swim a certain distance up a river and back than it does to swim the same distance across the river and back. The difference in time is caused by the fact that the swimmer has to swim for a greater time against the stream than with it. Careful repetitions of the experiment by Michelson, Kennedy, Pease and finally Joos (1931), have shown no difference in time. This result indicates that there is no ether current. Other experiments have been performed to determine whether the ether moves with the earth. The results indicate that it does not.

The blow to classical physics was not the fact that ether does not seem to exist; it was the conclusion deduced from this fact. Since ether does not seem to exist, it was concluded that there is no fixed system in space, and hence that all motion is relative; absolute motion does not exist. Another blow was the discovery that the measured speed of light is the
same regardless of the relative velocity of the source and the observer. According to Newtonian physics, this cannot be true; the speed of light equals its "absolute" velocity plus or minus the relative speed of the source and the observer.

**Einstein's Special Theory of Relativity.** The conclusion that all motion is relative was very disconcerting to those few physicists who could see its implications, and who were intellectually honest enough to face facts. Einstein was one of these few. He suggested, as explanation, his special theory of relativity which he based on two assumptions: (1) All motion is relative. (2) The measured speed of light is constant. Starting with these two assumptions he endeavored to predict by logical deduction the nature of the universe implied by them. Einstein had two guides: (1) Internal harmony of theory. (2) Experimental test of predictions.

A complete discussion of the development of the special theory of relativity, and of the other discoveries which conclusively proved the inadequacy of Newtonian physics, will not be attempted here. Nevertheless, it seems necessary to point out and discuss the following predictions which Einstein made on the basis of his theory:

1. The mass \( m \) of a body is a function of its velocity. The relationship is stated by the formula

\[
m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}
\]
in which $m_0$ is the mass of a body at rest relative to an observer, $v$ is the velocity of the body relative to the observer and $c$ is the velocity of light.

A simple test of this prediction was made by calculating the change in mass of the planet Mercury due to its velocity, and by using this mass for calculating its position. When this was done the calculated position (predicted position) was found to agree with the observed position. Thus a problem was solved which had remained unsolved for years.

The same variation of mass with velocity was tested over a wide range of much higher velocities. Bucherer and others found that the mass of moving electrons, having a velocity as high as 0.99 of the velocity of light, vary as predicted by the formula.

2. A beam of light will be bent by the gravitational field of a body. According to the wave theory of light, a beam of light should not be bent as it passes through the gravitational field of a heavenly body such as the sun; according to the corpuscular theory, it should be bent by the gravitational field of the sun an average amount of 0.75"; and according to Einstein it should be bent an average amount of 1.75". Attempts have been made to measure the bending of light rays during solar eclipses of the sun, and in each case the bending has been that predicted by Einstein.

Say Loeb and Adams, "...in every case where relativity has been put to a crucial test, the evidence has led to its complete
verification." However, relativity physicists do not believe that Einstein has discovered an absolute, never changing, invariable law.

Within certain limits, Newtonian physics is correct. But the absolutistic concepts, on which the philosophy is based, are false. Matter, space, time and motion seem not to be absolutes. The value of each depends upon its relationship to other things. For example, mass is dependent upon velocity; mass changes as velocity changes.

The Breakdown of Materialism. The experiment, which proved the futility of trying to find absolute knowledge in matter, was performed by Thomson. In 1925, Born and Heisenberg in their mathematical calculations assigned wave properties to electrons and were thereby enabled to explain several phenomena which until then had not been explained.

In 1927, Thomson reported passing high-velocity electrons through thin sheets of metal onto photographic plates and obtaining a diffraction pattern precisely like that produced by X-rays which are known to be waves. This finding indicates that high-velocity electrons are waves, not material particles. Until this discovery, electrons had been known to exhibit only the characteristics of material particles. If electrons are waves, then what is the real or absolute nature of matter?

A Newer Conception of Science. The Greek idealists made every effort to explain "why"; to explain everything in terms of purpose. They even believed that the behavior of inanimate objects is purposive.

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8 Loeb and Adams, The Development of Physical Thought, p. 166.
The Newtonian physicists did not assign purpose to anything. Machines, they believed, have no purpose. They tried to explain "how"; to visualize everything. Unless they could visualize a thing and build a working model of it, they doubted its existence. During the "teens" and "twenties" of the present century, elaborate models were made of different kinds of atoms in order to visualize and explain the behavior of their parts. Today, such models are almost unthought of.

According to Loeb and Adams, "It is quite probable that this craving for an explanation is as futile as the Greek's striving for an ultimate 'why'."9 Professor Kent of the University of Kansas says, "Physicists no longer attempt to picture and explain the behavior of an electron; its behavior is expressed in terms of a differential equation."10

What Truth Means to a Relativist. Another change of great importance in science is the meaning of truth. We have just seen that an electron, in one set of conditions, exhibits characteristics of waves; and in another set of conditions, exhibits characteristics of particles of matter. Is an electron a wave or a particle?

Before trying to answer this question, let us consider another example. If a ball is dropped in a train that is moving at a uniform rate relative to the track, to an observer in the train the path of the ball appears to be a straight line. To an observer outside the train, standing alongside the track, the

9 Loeb and Adams, The Development of Physical Thought, p. 170
10 Kent, C. V., Dr. Kent is Professor of Physics in the University of Kansas.
path appears to be a curved line (a parabola). What is the real or absolute path of the ball?

Relative to a frame of reference that includes only the train, such as that of an observer on the train, the path is a straight line. Relative to a frame of reference that includes the earth as well, such as that of an observer standing alongside the track, the path of the ball is a curved line (a parabola). There is no absolute path of the ball.

The apparent path to each observer depends upon the relationships sensed. In one configuration (frame of reference) certain relationships between the path, the environment and the observer are sensed; and in the other configuration, different relationships are sensed. As a result, each observer obtains a different impression of the path of the falling ball.

According to relativists, what one observes is a joint* phenomenon of the observer and the environment. Truth depends upon the relationships sensed by the observer. The statue in the sun is golden to one observer and silver to another. The same sun rises in the east and sets in the west. If the absolutists were consistent they could not tell whether the statue is golden or silver, or whether the sun is rising or setting.

With respect to the question "Is an electron a wave or a material particle?", for the relativists the answer depends upon the relationships sensed by the observer. If we define a wave

*Note: For a more detailed discussion of the relationship of the observer and environment (see p. 61).
and a particle as they are commonly defined, then an electron, to an observer in one configuration, may act as a particle; and in another configuration, may act as a wave.

A relativist believes that a thing, in and of itself, has no meaning. A thing has to be sensed as related to other things before it has meaning. The more relationships sensed, the more meaningful a thing is. This conception of meaning is the basic assumption on which the relativity theory of teaching is based. Since meaning depends on insight (sensed relationships), absolute truth does not exist. Truth is continually made and remade as new points of view and new understandings are developed; as new relationships are sensed.

Why Have the Relativists Been Successful in Science? In practice the scientific materialists' method of research consists largely of observation, analysis, and classification of knowledge. This method yielded many outstanding discoveries until about every discernible thing that naturally exists and occurs had been discovered. It was when the scientific materialists began dealing with things which they could not observe directly that they ran into difficulties.

No doubt, if scientists had continued to think and act in keeping with the philosophy of scientific materialism, Michelson's prediction, that "The future of discovery lies only in extending the accuracy of measurement to further significant figures," would have proved correct.

The secret of the relativists' success has been their ability to formulate hypotheses, on the basis of known knowledge,
for predicting new knowledge which has proved reliable when subjected to the most exacting experimental tests. Their final test for new knowledge is experimental only, and not agreement with antecedent, prior knowledge. In case new tested knowledge does not agree with old knowledge, the relativist turns his attention to the old to discover what is wrong with it. If he finds it is in error he corrects it so that the old and new harmonize or fit together.

The outstanding weaknesses of scientific materialism are the assumptions that facts speak for themselves, that absolute knowledge exists, and that it can be and has been found. The first assumption limits hypothesizing to very narrow limits, and the second and third limit the test of new knowledge largely to agreement with the known supposed absolute knowledge. Once our present knowledge is assumed absolute, there is no way to reconstruct it; there is no way to reconstruct the old in the light of the new; the new must always be made to fit the old. This is one of the crucial differences between absolutism and relativism.

A relativist favors neither old nor new knowledge, but always reconstructs and harmonizes the one in the light of the other as he pushes forward in search of the unknown. A relativist's chief tool for finding new knowledge is the intellect; not the sense organs. He does not believe that facts speak for themselves nor that only one interpretation--the one that agrees with prior knowledge and philosophy--can be made of facts. A relativist gives attention to WHAT IS (what he observes), but gives
far more attention to **WHAT MUST BE** if so-and-so is assumed to be true. A relativist theorizes, but does not belittle either the practical or the experimental, as did the idealists. A relativist tests his theories by experiment, but does not belittle theory, as did the early materialists and as scientific materialists do today. Internal consistency of theory and experimental test of new knowledge are the relativists' guides.

The relativists have really brought theory and practice together on equal footing, stripped of the influence of absolute, prior knowledge and other external authority, and are using them, one to re-enforce the other, to help gain a better understanding of the universe.

Although the philosophers—Peirce, James and Dewey—were the first to advocate the relativity principle, the physicists were the first to put it in practice. Both the philosophers and the physicists should be given due credit.

And even though the relativity theory has been very fruitful, and most of the outstanding physicists of today accept and use it, there is much opposition to it, as will be shown later. Any philosophy, that is as well intrenched as either idealism or scientific materialism has become in Western culture, will not die in half a century.

**A Wider Concept of Relativity.** The theory of relativity applies not only to physics and philosophy, but also to thinking in all fields of intellectual endeavor. It is known in biology as the organismic theory; its chief advocates are
Haldane, Ritter and others. In psychology, it is known as the organismic or Gestalt theory; among its outstanding advocates are Koffka, Koehler, and Wheeler. In mathematics, the theory is represented by the recognition of non-Euclidean geometries such as those of Riemann and Lobatschewski. In philosophy, its chief proponents are Peirce, James and Dewey; and in education, it is expounded by Dewey, Bode, Bruce, Bayles and others. In philosophy, it is known as pragmatism, instrumentalism and experimentalism.

The Problem. The problem which we propose to study is, "The Implications of the Theory of Relativity for the Teaching of Science." First we shall consider the influence, today, of scientific materialism on the teaching of science; and then we will attempt to determine how science should be taught in order to be in keeping with the theory of relativity as it is developed in science, psychology, philosophy, and education.
 CHAPTER II  

BEHAVIORISM AND ITS IMPLICATIONS FOR TEACHING SCIENCE

Before trying to formulate a consistent program for teaching, it is advisable to investigate the basic assumptions of various schools of psychology and to consider the implications of these assumptions for teaching. It is especially advisable to consider those schools which have had the most influence on teaching during the past few decades.

Without doubt, two psychologies, both proposed at the beginning of the 20th century, one by John B. Watson and the other by Edward Lee Thorndike, have had more influence on teaching in America during the past quarter century than all other psychologies. Watson's school of thought is known as behaviorism, but both schools are so much alike that they are classed by many as behaviorism.

Watson's Behaviorism. Since the mechanistic and materialistic philosophy of scientific materialism has been very fruitful in research in chemistry and physics, it is only natural to expect that this philosophy would influence research in other fields.

Behaviorism is an attempt to explain behavior in purely mechanistic terms; in terms of the laws of chemistry and physics. Watson says, "The behaviorist is a mechanist? Yes, utterly."¹ Weiss defines behaviorism in psychology as: "...that type of

¹ Watson, John B., The Ways of Behaviorism, p. 42
investigation and theory which assumes that man's educational, vocational and social activities can be completely described or explained as a result of the same (and no other) forces used in the natural sciences."²

In Chapter I, it was shown that the Greeks, even at the time of Socrates, were wrestling with the problem of dualism of mind (soul) and body (matter). Many of the best minds of the human race have wrestled with this problem. "...the story of this struggle is a record of futility."³ says Bode. "All psychology," says Watson, "except behaviorism is dualistic."⁴ Behaviorism is an attempt to eliminate this dualism.

Since mind cannot be seen or analyzed, as a chemist analyzes a chemical compound, the behaviorist

...dropped from his scientific vocabulary all subjective terms such as sensation, perception, image, desire, purpose, and even thinking and emotion as they were subjectively defined...

The behaviorist asks: Why don't we make what we can observe the real field of psychology? ...Well, we can observe behavior—what the organism does or says...saying is doing—that is, behaving. Speaking overtly or to ourselves (thinking) is just as objective a type of behavior as baseball.⁵

In other words, Watson denies that mind can be treated scientifically and hence does not consider it. Everything that counts is: "Can I describe this bit of behavior I see in terms of 'stimulus and response'?"⁶ And in order that behaviorism may become scientific, says Watson,

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³ Bode, Boyd Henry, Conflicting Psychologies of Learning, p. 131
⁴ Watson, John B., Behaviorism, p. 4
⁵ Ibid, p. 8
⁶ Ibid, p. 8
It is the business of behavioristic psychology to be able to predict and to control human activity. To do this it must gather scientific data by experimental methods. Only then can the trained behaviorist predict, given the stimulus, what reaction will take place; or given the reaction, state what the situation or stimulus is that has caused the reaction.7

Thus Watson assumes that for each response there must be a definite stimulus. Knowing the response, he assumes that it is possible to know the stimulus; or, knowing the stimulus, it is possible to predict the response.

Man is an animal born with certain definite types of structure. Having that kind of structure, he is forced to respond to stimuli at birth in certain ways...8

Thus we see that an infant, like a machine, behaves as it does because it is constructed in a certain way. Response to a given stimulus is determined by the neural pathway that conducts the sensory impulses from the sense organs to the motor organs. The whole action is as mechanical, leaving out the person who does the dialing, as the action of a dial telephone system. Responses which an organism makes at birth, Watson calls unlearned responses. These modes of response are called reflexes.

Seemingly, each reflex action is an element and is complete, in and of itself. It has meaning, in and of itself, and can be explained without reference to past or future acts.

7 Watson, John B., Behaviorism, p. 11.
8 Ibid, p. 74.
"The organism," says Watson, "starts out in life with more unit responses than it needs."9 Yet the number of unconditioned, unlearned responses is too small to care for the adult... there are thousands of simple unlearned and unconditioned responses, such as finger and arm movements, These are the elements out of which our organized, learned, responses must be formed..."10

Since the neural pathways are laid down at birth and the responses to stimuli are fixed, that is, determined by the neural pathways which conduct the sensory impulses, then the only way to enlarge the number of stimuli to which we respond, that is to learn, is to modify the pathways that conduct. This can be done by coupling a stimulus with a new response. A reflex action which is created by joining an old stimulus to a new response, or a new stimulus to an old response, is called a conditioned reflex.

The method of coupling a new response with a stimulus is based upon the work of Pavlov who discovered that by presenting a dog with food and ringing a bell at the same time, after several repetitions, the dog's mouth will water when the bell is rung in absence of food just as in presence of food. Thus by substituting the sound of the bell for the odor or sight of food, a dog can be taught to make a new and definite response to a stimulus which previously did not cause this new response. The response is a learned response or conditioned response.

Learning of every kind consists ultimately in the building of conditioned reflexes. Out of the simple reflex acts, both

9 Watson, John B., Behaviorism, p. 24
learned and unlearned, habits are formed. "These simple, unconditioned, embryological responses, by the presentation of appropriate stimuli...can be grouped and tied together into complex conditioned responses, or habits...These complex responses are thus integrations." 11

To understand the formation of basal habits, Watson says,

Take a baby brought up on the bottle. When he is three months of age, slowly present the bottle of milk. When it is close to him, almost within reaching distance, you will find that his body begins to wriggle and squirm, his hands, feet and arms become slightly active, his eyes fixate, his mouth moves, he cries, but he does not extend his arms towards the bottle...Repeat the procedure the next day...The chance of the arms and hands striking or touching the bottle before the rest of the body is great...

Once the bottle...is touched, the hand closes over it (unlearned grasping). It is then carried to the mouth (part of a habit system previously learned). In 30 days, by giving the baby 10 or 12 trials of this kind each day, the habit of reaching for a small object and carrying it to the mouth becomes nearly perfect.

Note, finally, that as the arm, hand and finger movements are perfected—that is, as the response becomes more highly organized—movements not related to the business in hand, such as this instance those of the trunk, legs and feet die away. In its perfected form, reaching takes place with perfect efficiency;... 12

Thus, according to Watson, when learning takes place, habits are formed by conditioning useful responses and eliminating useless responses. The useless responses "die away."

11 Watson, John B., Behaviorism, p. 24
12 Ibid, pp. 162-163
Let us consider another learning situation which Watson cites as an example of the growth of habit. In this experiment Watson puts in front of a three-year-old child, whose habits of manipulation are well established, a problem box which the child knows contains candy.

To open the box, the child has to press inward a small wooden button. Watson says:

This situation is new to him. None of his previously formed manipulation habits will completely and instantly work in this situation... What does he do?... (1) he picks the box up, (2) he pounds it on the floor, (3) he drags it round and round, (4) he pushes it up against the baseboard, (5) he turns it over, (6) he strikes it with his fist. In other words, he does everything he has learned to do in the past in similar situations.  

Finally after many attempts he opens the box. If he has fifty learned and unlearned separate responses at his command, according to Watson, he will display nearly all of them, unless one of them is the correct one. The next time the child tries to open the box, he makes fewer movements; the third time fewer still. "In 10 trials or less he can open the box without making a useless movement and he can open it in two seconds."  

If we plot a curve showing the relationship of the number of trials to the number of random movements for each trial, we get a sloping curve which shows that random and useless responses gradually die out and that finally there is one definite response; no other. All the others have been eliminated. A certain response has been coupled with a certain stimulus.

13 Watson, John B., Behaviorism, pp. 164-165.
14 Ibid, pp. 165.
From the description of the child's behavior, it is evident that Watson believes all learning, even learning in novel situations, is nothing more than habit formation. The learning of complicated behavior is nothing more than getting the proper reflex acts in the proper order.

Furthermore, he believes that in performing an established habit, the first act stimulates the second and so on. The whole process is mechanical; and once it is set in action it continues. Watson says, "The muscular stimuli coming from the movements of the muscles themselves are all we need to keep our manual responses occurring in proper sequence." 15

Even thinking, we are warranted to believe, is habit. Watson says, "And let me make this fundamental point at once: that saying is doing—that is, behaving. Speaking overtly or to ourselves (thinking) is just as objective a type of behavior as baseball." 16

Since thinking is as objective a type of behavior as playing baseball, and because playing baseball is habit formation just as much as is opening the candy box, then the only logical conclusion is that learning to think is a habit, and thinking is a habit which is learned in the same way that a child learns to open Watson's problem box. All behavior consists of either natural or conditioned reflexes.

16 Ibid, p. 6.
From what has been presented, we see that the basic assumptions of Watson's behaviorism are far reaching for teaching. However, before considering their implications let us consider the basic assumptions of Thorndike's psychology. Then we shall summarize the assumptions of both, and discuss their implications for teaching and for the formulation of a teaching program.

Thorndike's Psychology. According to Thorndike, man is born with certain original or unlearned tendencies to respond in certain ways. He says:

When the tendency concerns a very definite and uniform response to a very simple sensory situation, and when the connection between the situation and the response is very hard to modify and is also very strong so that it is almost inevitable, the connection or response to which it leads is called a reflex... When the response is more indefinite, the situation more complex, and the connection more modifiable, instinct becomes the customary term... When the tendency is to an extremely indefinite response or set of responses to a very complex situation, and when the connection's final degree of strength is commonly due to very large contributions from training, it has seemed more appropriate to replace reflex and instinct by some term like capacity or tendency or potentiality. 17

These original tendencies of man says Thorndike:

...constitute an enormous fund of connections or bonds of varying degrees of directness and strength between the situations..., and the responses of which the human creature is capable. 18

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Any neuron will, when stimulated, transmit the stimulus, other things being equal, to the neuron with which it is by inborn organization most closely connected.

They (original connections) (parentheses our) are the starting point for all education or other human control. The aim of education is to perpetuate some of them, to eliminate some and to modify or redirect others.19

According to Thorndike, the bulk of animal learning is in accordance with two laws. They are:

The Law of Exercise comprises the laws of Use and Disuse. The Law of Use is: When a modifiable connection is made between a situation and a response, that connection's strength is, other things being equal, increased.20

The Law of Disuse is: When a modifiable connection is not made between a situation and a response during a length of time, that connection's strength is decreased.21

The Law of Effect is: When a modifiable connection between a situation and a response is made and is accompanied or followed by a satisfying state of affairs, that connection's strength is increased; when made and accompanied or followed by an annoying state of affairs, its strength is decreased.22

In order to get a more concrete idea of Thorndike's philosophy, let us consider some of the pioneer experimental work that he did in the field of animal learning. To discover how a cat learns, Thorndike placed a cat in a cage after it had been deprived of food for some time, and outside the cage he placed food where it could be seen by the cat, but could not be reached.

21 Ibid., p. 4.
22 Ibid., p. 4.
The result was that the cat reached through the bars, scratched them, tried to squeeze through them, walked nervously from one corner to another, reared up on its hind legs and stood with its paws against the side of the cage, and did other such acts in regular cat fashion. Finally, it accidentally pulled a string hanging in the cage and the door opened, letting the cat out. "Thus the successive times taken by one cat in a certain box were (in seconds) 160, 30, 90, 60, 15, 28, 20, 22, 11, 15, 20, 12, 10, 14, 8, 6, 6, 7." 23

If we plot a curve of time-in-seconds and number-of-trials, we get a curve of considerable irregularity, but one which shows a gradual slope downward and indicates that wrong responses gradually tend to drop out.

In Thorndike's view, learning is the establishment of a new neural pathway, so that a certain stimulus produces a certain reaction to the exclusion of all others. A certain response is coupled with a certain stimulus. This is done according to the laws of learning. Those responses which bring about the greatest satisfaction are "stamped in." Those that are stamped in are the ones that have the greatest tendency to be repeated; and repetition helps to stamp them in. Annoying responses are stamped out.

Thorndike's philosophy, like Watson's, is based on the stimulus-response (S-R) or reflex arc theory. The motivator of an activity is a stimulus which sets off a nervous impulse.

which in turn sets off the response. Given a certain stimulus, the response is determined by the bond which conducts the nervous impulse. Thorndike says, "...in the same organism the same neurone-action will always produce the same result—in the same individual the really same situation will always produce the same response."24

When two seemingly identical stimuli cause two different responses, Thorndike explains the responses as follows. "First, the apparently same situations may really be different... Second, if the situations are really identical, the apparently same organism really differs...the really same response is never made to different situations by the same organism."25 Thus to change behavior the conducting pathways or the stimulus must be changed.

Up to this point in our discussion we see that Thorndike is fairly consistent. Thorndike, like Watson, denies that purposive behavior, which implies mind, can be treated "scientifically." For this reason both of them ignore or circumvent purpose and mind. But, in spite of what they deny and say they ignore, we saw that Watson in his experiment, already described, put a piece of candy in his problem box and showed it to the child before closing the lid, and that Thorndike in his experiment put a hungry cat in a cage and put food outside of the cage where the cat could see it. In each case, the experimental subject had a definite goal; something which it wanted very urgently.

25 Thorndike, E. L., Educational Psychology, Briefer Course, pp. 6-7.
Another glaring inconsistency is Thorndike's Law of Effect. Thorndike, in "Educational Psychology (Briefer Course)," devotes several pages to a rather vague explanation of what he means by satisfaction and annoyance. He says:

By satisfying state of affairs is meant roughly one which the animal does nothing to avoid, often doing such things as attain and preserve it. By annoying state of affairs is meant roughly one which the animal avoids or changes.26

In order to be more specific, Thorndike gives several examples. To eat when hungry is satisfying; to eat when satiated is usually annoying. Being with friends is satisfying; being with strangers is usually annoying. We like sweet foods better than bitter ones; we like to sleep when weary and tired; and we like to move when refreshed. Being checked when in locomotion and being looked at with scorn are unsatisfying. Running after an animal which arouses hunting behavior, getting nearer to it in the course of running, jumping upon it, seizing and subduing it, are all satisfying. Pulling a string that opens the door of a cage is satisfying to a hungry cat in the cage. Pulling an identical nearby string which does not open the door is annoying.

Seemingly, Thorndike believes that each of these acts is either satisfying or annoying, in and of itself. Neither satisfaction nor annoyance is dependent upon a preceding or a future act.

26 Ibid, p. 50.
However, if an act is satisfying or annoying, in and of itself, it is difficult to understand why pulling a string which opens the door of a cage is any more satisfying to a cat than pulling a nearby identical string which does not open the door. And, it is still more difficult to understand why pulling the string which opens the door is not as satisfying to a hungry cat when food is inside the cage as when it is outside the cage. Surely there must be some relationship between a satisfying or annoying act and an organism's goal; what it wants.

Satisfaction and annoyance are easily explained in terms of goal. When food is outside the cage, the cat senses that pulling a certain string opens a door which allows it to reach the food; hence the act is satisfying. When the food is inside the cage, the cat senses that there is no relationship between pulling the same string and its goal; hence the act is annoying. Goal, and the ability of the cat to sense a relationship between an act and its goal, imply mind which Thorndike and Watson claim cannot be treated scientifically.

No doubt, Thorndike would explain why pulling a certain string is satisfying when the food is outside the cage and why the same act is annoying when food is inside the cage in terms of his Law of Readiness. It is:

When any conduction unit is in readiness to conduct, for it to do so is satisfying. When any conduction unit is not in readiness to conduct, for it to conduct is annoying. When any conduction unit is
in readiness to conduct, for it not to do so is annoying.27

Probably, his explanation would be as follows: If the food is outside the cage, the bond that conducts, when the string is pulled, is in readiness to conduct. Hence, the act is satisfying. If the food is inside the cage, the bond that conducts when the same string is pulled, is not in readiness. Hence, the act is annoying. The change in the environment or situation causes an internal change in the cat.

But what causes a bond to be in readiness other than a goal? When food is outside the cage, a certain bond is in readiness. When the food is inside the cage, a different bond is in readiness. Consequently, there must be a direct relationship between goal and readiness of a bond to conduct.

Further in his discussion of satisfaction and annoyance, Thorndike says that "when any original behavior series is started, any failure of it to operate successfully is annoying."28

"Successful," as Thorndike uses it, is as indefinite as "satisfaction." For a person to be successful, usually means that he accomplishes his purpose; that he gets what he wants. Our definition implies purpose, which in turn implies mind. The Law of Readiness, instead of explaining away goal and purpose, as Thorndike evidently designed it to do, seems to substantiate both.

Thorndike, like Watson, makes learning the development of habits. However, Thorndike's method of development is slightly different from Watson's. Watson recognizes no difference between animal and human learning as Thorndike does. That Thorndike recognizes a difference is shown by the following:

Were the reader confined in a maze or a cage, or left at some distance from home, his responses to these situations would almost certainly include many ideas, judgments or thoughts about the situation; and his acts would probably in large measure be led up to or 'mediated' by such sequences of ideas as are commonly called reasoning. Between the annoying situation and the response which relieves the annoyance there might for the reader well intervene an hour of inner consideration, thought, planning and the like. But there is no evidence that any ideas about the maze, the cage, the food or anything else, were present to determine the acts of the chicks or kittens in question. 29

Even though Thorndike recognizes this difference between animal and human learning, he staunchly insists that human learning, like that of other animals, is conditioning reflexer, for he says:

If any learned response is made to the situation (the one mentioned above)... it is due to the action of use, disuse, satisfaction and discomfort. There is no arbitrary hocus pocus whereby man's nature acts in an unpredictable spasm when he is confronted with a new situation. His habits do not then retire to some convenient distance while some new and mysterious entities direct his behavior. On the contrary, nowhere are the bonds acquired with old situations more surely revealed in action than when a new situation appears. The child in the presence of a new object, the savage with a new implement, manufacturers making steam coaches or motor cars,

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In all such cases, old acquisitions are, together with original tendencies, the obvious determiners of response, exemplifying the law stated above. 30

Apparently, human reasoning is simply complicated behavior similar to the behavior of the cat "learning" to get out of the cage. Human behavior differs in that it involves "sequences of ideas as are called reasoning." The human being can plan and meditate; that is, reason. This a cat cannot do. However, this behavior is not new. "In all such cases, old acquisitions are, together with original tendencies, the obvious determiners of response." In other words, thinking or reasoning is a sequence of learned and natural reflexes. These reflexes are put together in proper sequences like beads on a string in the same way that a cat puts reflexes in a sequence in learning to get out of a cage. Responses to a new situation are nothing more than a rearrangement of old responses. Each act is a replica of a preceding act. There is no such thing as creative behavior.

To any new situation, says Thorndike, man responds as he would to some situation like it, or like some element of it. Man's intellectual supremacy is due to the fact that he is able to isolate and respond to elements which for animals remain intricably inbedded in gross total situations.

In other words, man can deal with new situations because he detects elements in them which are not at all new, but are already known.

Man's intellectual supremacy is due to the fact that he is able to isolate and respond to elements which for animals

30 Ibid, p. 149.
remain inextricably imbedded in gross total situations. A horse can be taught to open a gate by teaching him to lift a latch, but if a sliding bolt is substituted for the latch, the horse cannot open it. A human being would detect that the sliding bolt accomplishes the same result as the falling latch and that the gate can be opened by sliding the bolt.

According to Thorndike's theory, Newton was able to formulate the universal laws of falling bodies because he was able to detect the common element between the path of the moon and that of a falling apple here on earth. That is, Newton knew that at any particular point in the path of the moon, the velocity of the moon may be thought of as consisting of two components, one of which is toward the earth. Newton computed the value of this component and found that the moon falls towards the earth about 15 feet per minute. This velocity is the same as the calculated velocity of a freely falling body that is the same distance from the earth as is the moon. It was this common element that Newton discovered. And even though the discovery was a stroke of genius, it was nothing more than the application of an old habit.

The application of past habits to new situations is limited to those in which an identical element exists. Solving a new problem is a process of analysis; a process of analyzing out the identical elements. "Every new problem," says
Sandiford, "must be twisted into the form of an old problem whose solution is already known; otherwise it can never be solved." 31

In learning, this philosophy allows for no synthesis or harmonization. It allows for no reconstruction of old knowledge in the light of new knowledge, as Einstein reconstructed old knowledge in formulating his special theory of relativity. The ability of one to sense new relationships between the old and new, to reconstruct both in the light of each other, and to use the reconstructed knowledge to predict new knowledge is completely denied by implication. Likewise, the philosophy of relativity science, proposed in Chapter One, is denied.

Besides the laws of readiness, Exercise and Effect, learning is, according to Thorndike, affected by five other subsidiary principles. Most of these were exemplified by Thorndike's cat in learning to escape from the cage and by the examples of learning which we have cited.

The first is the Law of Multiple Response or Varied Reaction. Failure on the part of a cat to get out of a cage one way results in an inner change. This change causes a new reaction to the same external situation. One's different reactions to a groaning dinner table are dependent upon physiological conditions in oneself; whether one is hungry or not.

The second, Thorndike calls Set or Attitude. An example is: the hungrier a chicken is and the more vitality it has, the more eager it is to escape from a cage in which there is no food.

31 Sandiford, Peter, Educational Psychology, p. 298.
The third is the Law of Partial Activity. An example is that if a cat has learned to escape from a number of different boxes, its responses are a mixture of responses to those confining objects like the confining objects in other boxes.

The fourth is the Law of Assimilation or Analogy. Newton's discovery of the law of universal gravitation by recognizing the analogous elements of the two different situations is a good example.

The fifth is the Law of Associative Shifting. Thorndike's example is that if a fish is held above a hungry cat and a verbal signal is given at the same time, a cat can be taught, after several repetitions, to stand on its hind legs in absence of the fish when the verbal signal is given.

Let us examine these principles closely. What causes set or attitude other than a goal? Change the goal and the set or attitude will change. Change a boy's ideals (goal) and watch his behavior change.

What do the Laws of Multiple Response, Partial Activity, and Assimilation imply other than that an organism is capable of making choices among stimuli? That is, the animal can sense a relationship between certain stimuli and its goal and it seems to react to these in terms of the sensed relationship. This ability is known as insight and implies mind. Watson and Thorndike deny that mind has any place in scientific psychology.
The Law of Associative Shifting is nothing more than Watson's conditioned reflex. It, and the Law of Exercise, are thoroughly in keeping with Thorndike's denial of mind and purposive behavior.

Seemingly, Thorndike is a past master at circumventing what he denies. Time and again he infers goal and even speaks of insight. He does everything except use the term mind. Most scientists agree that internal consistency is a prime requisite of any theory; and critic after critic has pointed out Thorndike's inconsistencies, yet he has made no effort to rectify them. Thorndike's attitude toward his critics is entirely different from that of Einstein, who has made special effort to rectify every inconsistency that has been pointed out in his theory. Einstein considers his critics as valuable assets.

Of the two, Watson and Thorndike, Watson is by far the more consistent. Watson denies the Law of Effect because he sees that it implies goal, and he makes no distinction between the behavior of human beings and other animals because he sees that a distinction is not in keeping with his denial of mind and purposive behavior.

The Assumptions of Behaviorism. The fundamental assumptions of behaviorism, which are important for formulating a teaching program, are listed below:

1. The motivator of any activity is a stimulus; it sets off the sensory impulse which in turn sets off the response.
(2) All behavior is non-purposive; it is as mechanical as the action of a dial telephone system; or the action of the solar system.

(3) Given a certain stimulus, every act is determined by only one factor, the neural pathway which conducts the sensory impulse. To change behavior, change the pathway that conducts.

(4) At birth the pathways are laid down; however, certain of these may be modified. Nevertheless, every learned act is a replica of some other act which has preceded it. There is no such thing as creative action in human behavior.

(5) Every stimulus is a unitary phenomenon, complete in itself; its action ceases before the response gets underway; the stimulus is therefore unchanging.

(6) Every response is a unitary phenomenon complete in itself; it proceeds as soon as the impulse reaches the motor organ. The response too is unchanging.

(7) Complex action and habits are made up simply of additive combinations of simple acts. In the performance of a habit, the doing of the first act serves as the stimulus for the next act and so on. The whole act is done automatically. It is mechanical and requires no direction.

(8) Thinking, reasoning, insight and reflective thought are all habits.

The Implications of Behaviorism for Teaching. The implications of behaviorism for teaching are far reaching because
so much emphasis is put on environment. Seemingly, the child's "mind" is like putty; it can be molded any way desired. Watson says:

If you start with a healthy body, the right number of fingers and toes, eyes and the few elementary movements that are present at birth, you do not need anything else in the way of raw material to make a man, be that man a genius, a cultured gentleman, a rowdy or a thug.32

In other words, a pupil is assumed to be passive; just so much raw material awaiting the manipulation of the teacher. Teaching is concerned with the task of connecting certain responses with certain stimuli. Because each reflex act is a whole—complete in and of itself—emphasis is put on learning the elements; the facts. These are usually taught and learned in and of themselves; and as a result, learning becomes largely memorizing and is mechanical. Once the proper response can be made to the elemental stimuli, the elemental responses are fused.

A good example of such teaching is the method by which the writer was taught to read. First, the letters of the alphabet were taught; when these were learned, words were taught; afterwards, reading was taught.

Spelling, as taught in most schools in America, is another example of this type of teaching and learning. Below is a list33 of words for third and fourth grades, taken from a speller that was chosen at random from a number of spelling books:

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32 Watson, J. B., Psychological Care of Infant and Child, p. 41.
got cook rain dried
wood supper glad burned
fire meat put buys

In no instance is there any relationship, as far as spelling is concerned, among the words. Each word has to be memorized in and of itself. A definite response has to be tied up with a certain stimulus.

Out of several hundred lists, the following is the only list in which words are arranged so that spelling relationships among words might be discovered:

need heel wall beet
feet tall hall calls
meet wheel fall falling

In order to learn things in isolation—that is, to fix responses—much repetition or drill is required. For this reason, drill pads and workbooks of a mechanical nature have been written and sold for every subject taught from first grade to twelfth.

The emphasis in teaching is on making the "proper" responses to stimuli; that is, on fixing "desirable" habits and "desirable" attitudes. Habit formation becomes paramount. Watson says:

We are constantly manipulating stimuli, dangling this, that and the other combinations in front of the human being in order to determine the reactions they will bring forth—hoping that the reaction will be "in

34 Ibid, p. 19.
line with progress," "desirable," "good." (And society really means by "desirable," "good," "in line with progress," reactions that will not disturb its recognized and established traditional order of things).\(^35\)

In other words, pupils' attitudes and habits are to be molded so that the pupils conform to the existing order of things. If certain forms of art are labeled great, if a certain church is believed to be better than others, if a certain political party is considered better than others, if certain customs—such as monogamy, installment buying, high interest rates, truth-telling, owning property, controlling prices through monopoly, making human sacrifices, fighting wars and voting—are held to be desirable and even sacred, children are to be indoctrinated with these ideas for no reason other than that they belong to the "recognized and established traditional order of things." If city government is run by racketeers, machine politicians, "big" business, labor unions, or even is democratically controlled, the pupil is supposed to conform because such things, if maintained, will not disturb the established order.

In passing, the question might be raised, What would be the status of affairs if Christ, Copernicus, Galileo, Hume, Calvin, Washington, Jefferson, Lincoln, Einstein, and even Franklin D. Roosevelt had been conformists?

It is in the field of curriculum construction that the implications of behaviorism are most far-reaching. In order to establish the "proper" attitudes and habits, it is necessary that these be chosen by someone. Since a child is to be molded to fit society and to promote the established order, it is only natural that representatives of the order should choose the attitudes and habits which are to be established. These are usually chosen by teachers, principals, superintendents, curriculum experts and members of pressure groups. Such a diverse group, as far as society is concerned, supposedly insures that the curriculum is constructed in a "democratic" manner.

In order that skills, habits and attitudes may be determined "scientifically," a method of analysis is used. Bobbitt says:

The first task is to discover the activities which ought to make up the lives of men and women; and along with these, the abilities and personal qualities necessary for proper performance... The plan to be employed is activity-analysis."36

"The activities once discovered, one can see the objectives of education."37 In other words, like the early materialists, Bobbitt believes that facts speak for themselves (see p. 3).

As a result of such a philosophy, in constructing a curriculum, widespread analyses are made of textbooks, the most

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36 Bobbitt, Franklin, How to Make a Curriculum, p. 8.
widely-read current literature, scientific books and magazines, movies, expert opinion and the community. The search is to discover **WHAT IS**. Examples of such analyses are:

Finley & Caldwell analyzed for biological materials the daily issues, for seventeen months, of newspapers representative of various sections of the country and 3,061 articles were found and analyzed; Garrison and Taylor analyzed certain issues of Literary Digest, National Geographic, Saturday Evening Post, American and other such magazines for botanical content.

Almost every **science** teacher is familiar with the very competent study made by Dr. Curtis, entitled "A Synthesis and Evaluation of Subject-Matter Topics in General Science." About twenty different sources of data were used which included three courses of study, four textbooks, six studies of scientific interests of children, three published reports of analyses of newspapers and magazines for science topics appearing therein, and other data of similar nature. The final outcome was 1,850 topics, each of which was given a mark indicating its relative value as determined by frequency of appearance. Frequency of appearance was the criterion used for choice of subject matter. After the study was completed, Curtis wrote a general science textbook and indicated in the book the most important topics, as determined in the study.

Hovde made a word-for-word analysis of fifteen textbooks in high school chemistry and compared the content with the analysis of the chemistry found in literary, home, story and children's magazines.
Other analyses have been made, running into the hundreds. Seemingly, almost every doctor's or master's thesis that has been written in science education during the past twenty years has been concerned with some kind of analysis, each investigator trying to find out "what is."

Once the analysis is made, the objectives "speak up" for themselves. Then the subject matter is organized in different fields so that the "proper" objectives are attained when the subject matter is taught. This whole procedure is "scientific" curriculum construction par excellence.

We do not question the accuracy of the analyses or the methods used in making them, but we do question the assumptions and philosophy on which this so-called scientific curriculum construction is based. The assumptions are:
(a) that frequency of appearance in everyday life is the criterion which determines what subject matter is of most importance in a given course--"what is" is good and "what is not" is bad, and (b) that facts speak for themselves.

Frequency of appearance in newspapers and magazines might be a very good reason why a particular item should not be taught in school because children will have ample opportunity to learn about it elsewhere, but this is a minor criticism.

One of the major criticisms of this method of choosing subject matter is that it puts society in a "vicious circle," and is in opposition to the philosophy and spirit of science. The true purpose of science is to shape trends; that is, to
control environment. Instead of shaping trends, the behaviorists try to find out what the trends are so that children may be taught to conform to them.

If we make a study of the ideas presented in the Saturday Evening Post, Liberty, Colliers or other such magazines that are widely read, we find that the most frequently presented ones are ways and means for return to the hybrid, autocratic-laissez faire brand of economic, governmental, and social organization which existed prior to 1929. If such material is chosen, the school becomes a propaganda agency for promoting a pet doctrine of a particular influential group.

If we analyze the New Masses, the Daily Worker and other Communistic literature, we find another autocratic, pet doctrine expounded. No matter what is chosen, the pupil is indoctrinated because he is afforded no opportunity to choose and to decide what is right.

To use frequency of occurrence of various items in textbooks, newspapers, magazines and elsewhere as the major criterion for choice of subject matter means that the school becomes an agency for promoting what is right rather than promoting methods of finding out what is right.

Of course, it is important, in formulating a program of action of any kind, to know what others believe and the data upon which their beliefs are based. But the most important thing in setting up any program of action, experimental or otherwise, is to know what is to be accomplished, to find out what the aims and objectives are.
Deciding upon aims and objectives and what is to be accomplished, is largely a philosophical question, not a question of finding out what is. Perhaps the point can be made clear by considering the following example: Scientists and engineers can design and build high speed airplanes, but whether these are used to improve the welfare of their fellow-men or to destroy their fellowmen is a question that can be answered only when the aims of a society are decided upon. Such a question is a philosophical question, not a scientific one. Since behaviorists deny goal, the fact that choice of subject matter is dependent partly upon aims and objectives which are not determined by an analysis of what is and by allowing facts to speak for themselves, is very hard for them to understand.

From the standpoint of a pupil, textbooks, lectures and laboratory manuals containing cookbook experiments are nothing more than antecedent, authoritative, dogmatic knowledge handed down from "on high." The teacher is the "high priest"; that is, the go-between for the pupils and the "divine authority." The teacher's word, and that of the textbook are the never changing, invariable, "divine" knowledge.

Opportunity to solve real problems which require pupils to hypothesize, to test hypotheses by experiment and to choose the hypothesis which best explains the pertinent data and can be used most reliably to predict new data is never made possible except as a side issue in the form of an outside activity.
Although acknowledgement of ability of pupils to solve real problems contradicts the basic philosophy of even the most recent science textbooks, in most of them such opportunities are offered in the form of outside activities which are placed at the end of chapters.

Analyses may be made of pupils' interests, but interesting knowledge can be as authoritarian and dogmatic as uninteresting knowledge. Anyhow, interesting knowledge does not necessarily allow pupils opportunity to discover, sense relationships, make choices and develop insight and scientific-mindedness any better than does uninteresting knowledge.

The supreme duty of a teacher, according to behavioralism, is to see that a pupil becomes thoroughly indoctrinated with the "chosen" knowledge. That is, the teacher is supposed to see that pupils can make the "proper" responses to the particular stimuli.

To determine whether a pupil can do this, a supposedly "scientific" tool has been invented—the objective test by which a pupil is usually limited to two, three, or four choices which have been formulated by the maker of the test. A pupil is not given opportunity to give the answer that he may desire and then back it up with facts. Instead, he is forced to choose from a limited number of answers that have been decided upon by the "chosen" few.

Surely by this time it can be understood why the relativists, who pay tribute to freedom of intellect, should not
want to base a program for teaching on such an absolutistic, mechanistic, authoritarian and static philosophy as behaviorism.

And, perhaps some readers are beginning to see that behaviorism is not in keeping either with democracy or with the true spirit of science.

Watson's disdain for democracy is shown by the following statement:

I am not arguing here for free anything--least of all free speech. I have always been very much amused by the advocates of free speech... the only person who ought to be allowed free speech is the parrot...38

38 Watson, John B., Behaviorism, p. 248.
CHAPTER III
THE RELATIVITY THEORY OF BEHAVIOR AND ITS
IMPLICATIONS FOR TEACHING SCIENCE

Questions Implied by Behaviorism. In the first chapter we pointed out that the relativists' test of a theory is whether it can be used reliably to predict new data, whether it explains all pertinent data and whether it satisfactorily answers all the questions which it implies.

In our study of behaviorism, several basic questions implied by behaviorism were raised. For example: Is learning the fixing of neural pathways? Does the same individual always make an identical response to the same stimulus? Is behavior of an organism purposive or non-purposive? Does the stimulus initiate the response or does the organism have a part in initiating the response? Are habits mechanical, fixed and difficult to change, or are they highly flexible? What is mind? Learning? Education?

In this chapter we wish to consider how adequately the behaviorists answer these questions, and also how adequately the relativists answer them. The latter answers make up a part of the basic assumptions of the relativity theory of teaching.

Is Learning Fixing New Neural Pathways? According to behaviorism, learning is the fixing of neural pathways or bonds, particularly in the cerebral cortex of the brain. Pathways are established according to the Law of Exercise. Retention of what is learned is due to the persistence of bonds.
The behaviorist's theory of learning implies that if the cerebral cortex, or even a small part of it, were destroyed or cut across, so as to destroy or sever a particular pathway necessary for a certain response, then the learning of this particular response should either be greatly retarded or made impossible. And in case a response has been learned, severing or destroying a portion of the pathway that conducts the stimulation should inhibit the response in much the same way that cutting a telephone line inhibits communication.

In order to test whether destroying any particular part of the cortex inhibits learning, Lashley subjected a number of rats to operation and cut across various parts of the cortex in every way possible. The average extent of injury was 31.1 per cent of the total surface area of the cortex, with a range from 1.5 to 81.2 per cent, and a distribution covering every part of the cortex. By this method Lashley believed he should be able to trace the neural pathways of conditioned responses through the cerebral cortex, just as the spinal paths of simple reflexes seem to have been traced through the spinal cord. In conclusion, Lashley says:

The data...suggest three diverse types of influence upon learning arising from brain injuries. First, for some problems, a retardation results from injury to any part of the cortex... The magnitude of the injury is important; the locus is not. Second, there may be a general retardation arising from any injury to which is added a specific retardation resulting perhaps
from sensory deficiency... Third, for still other habits there may be a complete absence of any affect upon learning from lesions of any extent or of any locus,...

Even where specific functions are restricted to definite areas, as in case of...brightness habits, the separate parts have diverse subordinate functions.\(^2\)

I am coming to doubt the validity of the reflex hypothesis, even as applied to spinal reflexes. There are many indications that the spinal reflexes are no more dependent upon isolated conduction paths than cerebral functions.\(^3\)

Lashley's conclusions of his experiments for testing retention of learned habits were almost identical with these conclusions.

Lashley's findings in toto tend to prove that the cortex acts as a whole or as a unit, and not as a bundle of separate pathways like the telephone wires in a cable. Even the specific-function areas seem to act somewhat as wholes. If one part either of a specific function area or of an association area of the brain is destroyed, up to a certain amount, the remainder of that area seems to take over all the work. It seems to integrate the responses in such a way that an animal is able to execute the learned acts.

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1 Lashley, K. S., *Brain Mechanism and Intelligence*, p. 66
2 Ibid., p. 123.
3 Ibid., p. 163.
It is precisely this 'integration', says Bode, of which mechanism is unable to give an adequate account. This process of integration means that the nervous system somehow organizes itself, not in terms of fixed connections, but with reference to an end or goal. Adaptation is achieved, not by 'stamping in' a connection in the nervous system, so that the stimulation will always travel along a fixed pathway, but in some more complex and more mysterious way. We seem forced to conclude that living matter has properties which defy explanations in terms of mechanical habit-formation. 4

Furthermore, Lashley's experiments prove almost conclusively that learning is not the establishment of isolated neural pathways. Learning seems to be far less mechanical than the behaviorists would have us believe. The relativists do not try to explain "how" learning takes place. They believe that effort to do so is as futile as trying to explain the behavior of an electron.

Does the Same Organism Always Make an Identical Response to the Same Stimulus? To answer this question, Wheeler and Perkins 5 placed three lighted compartments containing food in an aquarium as shown in the diagram and then put fish in the aquarium in front of the compartments. Certain fish

![Fig. 1. Apparatus for Goldfish Experiment. X indicates the starting place. B, M, and D represent bright, medium, and dim compartments respectively.](image)

4 Bode, Boyd H., How We Learn, p. 126.
5 Wheeler and Perkins, Principles of Mental Development pp. 82-85.
were taught to feed from the brightest, others from the
darkest and still others from the compartment of medium
brightness. After each entry to a compartment, the relative
spatial position of the intensities was changed.

In a short time the fish (forty-two in all) learned
to enter the correct compartment, whatever its position.
Afterwards, when the lights were "stepped up" in brightness
so that the dimmest light was as bright as the strongest of
the original combination, or when the lights were "stepped
down" so that the brightest became as dim as the dimmest of
the original combination, the fish continued to make cor-
rect choices.

These results, according to Wheeler, indicate that the
fish did not choose a light of given absolute intensity.
Instead a fish responded to a whole situation; it responded
to one stimulus in relation to other stimuli. In other
words, it responded to one phase of a situation in terms of
the situation as a whole. A particular response was not
coupled with a particular, absolute, never changing stimulus.

Seemingly, the meaning of a particular light of given
intensity changed as the relationships among the light in-
tensities changed. A particular light or stimulus had no
meaning in and of itself. Meaning of a thing to the organ-
ism seemed to depend on the relationships that the organism
sensed between the thing and other things.
Is Behavior of an Organism Purposive? In order to answer this question, let us consider Koehler’s work with apes. His experiments were different from Thorndike’s experiments with cats in that apes could usually solve the problems other than by accident (chance). Koehler provided a situation wherein the direct way to a goal was barred, but an indirect way was left open. The animal was placed in a situation to determine whether it could solve the problem by the indirect way.

In one experiment, Koehler placed a banana outside an ape’s cage beyond the reach of the ape and laid a stick on the floor within the cage. If the stick were placed so that it was not visible when the ape looked at the fruit, the problem was not solved immediately. But when the stick was placed so that it and the banana could be seen at the same time, the ape picked it up and used it to "fetch" the banana. Apparently, the ape perceived the stick in relationship to the goal; for, without hesitation, he used it as a means for securing the banana.

In another experiment, Koehler placed a banana outside the cage with a string attached to it and placed the unattached end of the string within reach of the animal. The ape was able without hesitation to pull the banana into the cage by means of the string.

In both experiments, none of the apes hesitated and made useless motions, as did Thorndike’s hungry cats. Each seemed

to sense the relationship between the objects at hand and the attainment of the goal. And the behavior of each seemed to be a continuously orderly sequence of acts, all adapted, in themselves and in the order of their sequence, to reach a certain objective; an end or goal.

The ability of an organism to sense relationships between its environment and the attainment of its goal, as has been said, is called insight. The development of insight is called learning. The relativity theory of learning is sometimes called the goal-insight theory.

Interpreting Behavior According to the Goal-Insight Theory. To interpret behavior according to this theory, three factors must be taken into account (1) goal, (2) environmental objects and (3) insights. Change any one factor or any combination of the three and behavior will change. The change can be predicted according to the psychological principle of least action which is: an organism acts in such a way as to achieve its goal in the quickest and easiest way that the organism comprehends at the time.

How an ape's behavior may change as his environment changes is shown in the experiment in which two bamboo sticks had to be fitted together by inserting one into the hollow end of the other so as to make a stick long enough to reach a banana outside the cage. In one instance, the stick was too large to be fitted into the other, so the ape proceeded to whittle down the end of the stick with his teeth, but in doing so he broke off a large splinter. Instead of cont'
to whittle the original stick, he inserted the splinter in the hollow end of the other stick and thereby made one stick long enough to reach the banana. As the tools or environment changed, the behavior changed in such a way that seemingly the goal was reached in the easiest and quickest manner comprehended by the ape; the changed behavior was in keeping with the psychological principle of least action.

An experiment that clearly shows how behavior changes as insight changes is Johnson's experiment with dogs. Johnson used two groups, one group whose eyelids had been sewed together in early puppyhood before the eyes opened and another group of normal, seeing dogs.

The animals of both groups were allowed to secure food from the box shown below; first through door A, then door B and finally through door C. The blind animals continued,

Fig. 2. Puzzle box of type used by Johnson in his experiment on dogs. Solid line represents path of seeing dogs after third rotation of box; dotted line represents path of blind dogs.

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after each change, to follow the pathway to the right around the box from the starting point as shown in Figure two; but the seeing animals when only C was open, after one or two trials, took the shorter pathway to left as shown.

Apparently, the blindfolded dogs could not sense the relationship between the goal and the shorter path, as the seeing dogs were able to do. Evidently, the insights of the seeing dogs were different from the insights of the non-seeing dogs; therefore, the difference in behavior.

The principle of least action is nicely illustrated by the behavior of an ape in one of Koehler's experiments in which he filled a box with rocks so that it was too heavy for the ape to move and placed it at one side of the cage so that the ape would have to move it in order to reach food suspended from the top of the cage. To move the box, the ape took just enough rocks from the box so that he could slide it. He did not remove all the rocks. Seemingly, the ape's acts were such that he reached his goal in the quickest and easiest way that he comprehended.

The Relativists' Conception of Sense Perception. According to the behaviorists, sensation, emotion, perception, memory and even thinking are just disturbances in the cerebral cortex. Mind is not subject to scientific investigation. All behavior consists of reflex acts. A complete reflex act is made up of three parts; a stimulus, a central adjustment and a response. A sense organ is stimulated by the environment
and this stimulation is transmitted to the cerebral cortex. This marks the end of the stimulus. In the cortex, the stimulation is transmitted to a neurone which transmits the stimulation to the muscles which act. In every case the stimulus precedes the response. The stimulus, originating in the environment, causes the response.

According to Dewey, the stimulus does not precede the response; the two operate simultaneously. Dewey says:

There is a certain definite set of motor apparatus involved in hearing just as much as there is in the subsequent running away. The movement and posture of the head, the tension of the ear muscles, are required for the 'reception' of sound. It is just as true to say that the sensation of sound arises from a motor response as that running away is a response to the sound.8

What Dewey means is that the listener is as much of a cause of the sensation of hearing as the stimulus which originates in the environment. The organism and the environment form a total whole and act together simultaneously. The organism and its environment are a unit; a configuration. The environment is no more the original cause of a sensation than is the organism (see p.16).

The interdependence of an organism and its environment, as far as sensations are concerned, can best be explained by an analogy taken from astronomy. The moon attracts the earth

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and the earth attracts the moon. The force of attraction is dependent upon both moon and earth. It is not caused by the earth alone, or by the moon alone.

Another analogy is the conception of what causes an object—for example, a table—to have weight. A table, in and of itself, has no weight. On the earth, the weight of a table is one amount; on the moon its weight would be another amount. The weight of a particular table depends (a) upon its own mass, (b) upon the mass of the other body or bodies concerned, and (c) upon the spatial relations among the bodies. Each of the bodies possesses a gravitational field. Weight of the table is derived from the interaction of the fields: Bode says:

All sense perception involves a field; which is to say that the physiological processes in sense perception involve corresponding changes in the field outside the body. In considering sense perception there is no occasion to refer to a 'mind' at all. To account for them we need to assume nothing beyond a physical organism in relation to its field.9

Hence, seeing, hearing, feeling and other sensations are all field properties which are derived from interaction between an organism and its environment. An organism is as much the cause of sense perception as is the environment.

9 Bode, Boyd H., How We Learn, p. 147.
What Is Mind? According to Dewey mind is, "...the power to understand things in terms of the use made of them..."10 That is, mind is the ability to sense relationships between environmental things, one's bodily skills, and the accomplishment of one's goal. A chair is something to sit on if we wish to eat at a table or wish to converse with friends in the home; something to stand on if we wish to remove an overhead light bulb; or something with which to defend oneself in a cafe brawl. Another definition of mind that Dewey gives is that "Mind is capacity to refer present conditions to future results and future consequences to present conditions."11

How We Learn. Many educators and others credit Dewey with the statement that we learn by doing. Anyone who has carefully read Dewey knows that this statement is not at all in keeping with his philosophy of learning. It is more in keeping with behaviorism—that we learn by repetition. Dewey does infer that we learn by way of experience, but is very careful about his definition of experience. "Mere activity" says Dewey "does not constitute experience."12 According to Dewey,

The nature of experience can be understood only by noting that it includes an active and a passive element peculiarly combined. On the active hand, experience is trying—a meaning which is made explicit in the connected term experiment. On the passive, it is under-

11 Dewey, John, *Democracy and Education*, p. 120.
12 Ibid., p. 163.
going. When we experience something we act upon it, we do something with it; then we suffer or undergo the consequences. We do something to the thing and then it does something to us in return. The connection of these two phases of experience measures the fruitfulness or value of the experience. It is not experience when a child merely sticks his finger into a flame; it is experience when the movement is connected with the pain which he undergoes in consequence.13

Unless one gets something which may be transposed from one situation to another and which enables one to see what will happen next or in a similar situation, and unless one gets something that develops foresight, understanding and insight, all of which increase control over future behavior, no learning takes place.

What is Education? According to Dewey, education is:

...that reconstruction or reorganization of experience which adds to the meaning of experience, and which increases ability to direct the course of subsequent experience.14

For a scientist, Dewey's definition of education should be very meaningful and easy to understand, for it embodies the whole of the method of science. It implies that education is reconstructing and harmonizing old and new experiences in terms of each other, and as a consequence the old and new experiences take on new meaning, thereby enhancing one's ability to predict future happenings and direct subsequent action in an efficient and fruitful manner.

13 Ibid., p. 163.
Learning and Habit Formation. In Chapter II, we found that according to behaviorists all learning is habit formation; it is a stamping-in of bonds; it is coupling a given response with a given stimulus. Once the bond is fixed, the same stimulus will bring forth the same response, except as the bond or connection is modified. Complex habits are formed by tying simple reflex acts together. Once a habit is fixed, it is performed automatically when the proper situation arises. The making of the first response is the stimulus for the second response and so on. The performance of a habit is purely mechanical. All behavior, even thinking, is a habit.

James wrote of habit as "an automatic, ready-made response." 15 Benson, Lough, Skinner and West define habit as "the relatively fixed way or combination of ways of reacting to situations." 16 Judd says, ... "habits are, in general, inflexible and unprogressive. They cannot be readjusted because of their fixity." 17

All of these interpretations of habit are thoroughly in keeping with behaviorism. All are seemingly based on the assumption that learning is the fixing of neural pathways, a fallacy which was disproved by Lashley.

We see at once that the assumption that learning is habit formation, and that habits are fixed, mechanical and nonpurpo-

15 James, William, Talks to Teachers, p. 66.
16 Benson, Jough, Skinner and West, Psychology for Teachers, p. 141.
sive, contradicts Dewey's theory that education is continuous and progressive reconstruction of experience. The definitions of habit given above and the whole philosophy of behaviorism, allow for no reconstruction of habit. When learning is left to an organism, no new learning can take place except by accident. The development of independent learners who can purposefully reconstruct their habits in such a way as to increase "the ability to direct the course of subsequent experience" is not recognized by behaviorists.

If the aim of education is to teach children to make the "proper" responses to a set of preordained, fixed and established stimuli—that is, to fit children to act as not to disturb the "recognized and traditional order of things," then, without question, teaching which will develop fixed, mechanical, non-purposeful habits is the type desired.

However, if we assume that society is dynamic, ever-changing, and ever-evolving, then teaching which develops the habit of reconstructing habits and enables man to control his environment, rather than allow environment to control him, is the type desired. The two points of view can be clearly shown by examples.

A savage tribe manages to live on a desert. It fits itself to the conditions which exist, but this fitting process involves accepting things as they are—toleration of present conditions, a minimum of active control of environment, and passive attitude towards things as they happen to be. Change is frowned upon, and if anyone tries to change
things, he is singled out for punishment. The result is that man is a victim of environment.

A civilized people enter the same desert. They introduce irrigation; they search for new plants that will grow under the conditions and can be used for food; and they improve these plants by breeding and selection. The result is that the desert blossoms like a rose. Man purposefully makes changes to see what happens. In this manner man learns to control his environment and thus becomes in a large measure the master of his own destiny.

The savage's habits cause him to conform to the existing order of things. Each year, at a certain time, the savage will be found doing the same thing in the same way that he did it the year before; his habits are routine, fixed, and in a sense non-purposive and mechanical.

The civilized man has habits too, but his habits are connected with a desire (purpose) to control and better his environment. He is not passive to existing conditions.

According to the relativists, as has already been stated, behavior is determined by three factors—insight, goal and environment. As long as these remain fixed, behavior does not change. For the desert tribe, all these remained fixed from one year to the next; consequently, there was little or no change in behavior.

Behaviorism denies purpose and insight. With these two factors eliminated, there is only one factor—environment—to influence behavior. Teaching practices based upon behavior—
ism tend to develop pupils who conform to the existing order of affairs. Pupils tend to habituate themselves in a passive way to their environment, just like a savage.

Recently, the author overheard a conversation between a teacher of manual training and a psychologist—a behaviorist. The teacher said that he had difficulty in teaching the boys in his classes to use the protective guards on power saws, and he wondered whether he should resort to punishment in order to teach the boys to use the guards.

The psychologist said, "Yes! If a pupil does not use the guards, hit him on the hands with a stick." Of course, as long as the teacher is in the room, boys taught in this manner will use the guards. But it is doubtful whether they will use them when the teacher is absent. The presence of the teacher is conducive to using the guards because it is a barrier to reaching the goal in the shortest and easiest manner.

In order to get the boys to use the guards in his absence, as well as in his presence, the teacher should change the boys' insights by making them aware of the consequences of not using the guards. After making them appreciative of the problem involved, a study of chance and probability might be a very effective way of doing this.

This could be done by having the boys flip pennies, roll dice and count the number of Fords that go by the school house during a certain period of the day for several successive days. From such a study the high degree of certainty of the law of
chance could be discovered. Then data concerning the chances that one takes of getting a hand cut off when using a power-saw without the guard could be presented.

Although the probability may be low, say one chance out of ten thousand, who knows when that one chance will occur? It might occur tomorrow when Jack uses the saw. Who would like to tie up Jack's arm with blood spurting from it in order to prevent him from bleeding to death before the doctor arrives? Who would want to inform his parents about the accident?

By using the guards, Jack can prevent the possibility of this accident; he can eliminate all chance. Safety posters made by pupils; dramas written and acted by pupils; all will help to develop understanding and insights concerning safety and help to build an environment that is conducive to making pupils safety minded. Thus, by changing insight, attitudes and environment, boys can be taught habitually to use the guards. But it should be recognized that the habit is not developed blindly and mechanically. These boys habitually use the guards because they realize the consequences of not using them. The change in behavior is purposive and intelligent; that is, the acts are performed with forethought of the consequences of the acts.

After all, it is doubtful whether a habit is as fixed as James, Judd and others believed. Let us examine a description of a skilled sawyer sawing a board to see whether this is the case.
When one drives the saw forward, it should engage the wood vigorously. When the saw is drawn back, it should pass lightly over the wood. The skillful sawyer makes his movements without stopping to analyze the experience; yet he is instantly responsive to the sensations which come from his saw. In such a phase of his movement as following a line or making a straight cut, the expert is guided by sensations in the palm of the hand. Let the saw swerve ever so little, and the skillful workman makes the necessary turn of his hand. He knows, further, how to adjust his stroke to different kinds of material; and he knows also that, when the board is very nearly divided, he must make a skillful stroke in completing the act.

In this description, adjustability rather than fixity is outstanding. Even the slightest changes in conditions seem to cause a change in actions. Seemingly, the acts of the sawyer are adapted, in the order of their sequence, to accomplish his purpose (cut the board straight across). Habits developed with purpose can be powerful intellectual tools for directing subsequent acts in a fruitful and efficient manner. Hence, according to goal-insight theory, the formation of such habits should be an aim of teaching.

The Relativists' Conception of Thinking. Thinking, according to the relativists, has three distinct meanings.

First, thinking means to recall or remember something. For example, Mr. Jones wishes to know where he left his missing umbrella. By thinking "hard" he remembers or recalls that he left it at his office behind the door. This type of thinking is known as recollection or memory-level thinking. It is perhaps the dominant type done in most schools today.

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Second, thinking means logical deduction; it is if-then thinking; the type commonly employed in geometry. Bayles says:

Thinking in this sense is a process of following out accurately the logical implications of a proposition. It is logical thinking; straight thinking; thinking in accordance with a given system; deductive reasoning; if-then thinking. In order to evoke such thinking at a given time, it is necessary merely for a properly trained individual to recognize its suitability, and, of course, be disposed to act appropriately. Therefore, we will call it recognition-level thinking. Whereas recollection-level thinking depends primarily on memory, recognition-level thinking depends primarily on understanding.19

Recognition-level thinking involves no hesitation in thought. One thought quickly, easily and logically follows from the preceding thought. Alternative situations do not have to be considered. The following is an example:

Major premise: All men are mortal
Socrates is a man
Therefore: Socrates is mortal

Another example of recognition-level thinking is the thinking involved in solving the following example wherein pupils know how to solve simultaneous equations, and understand the principles of transmission of sound through air and water: A sound is heard 15 seconds under water before it is heard in air; how far away is the source?

If a pupil understands the example and the principles which apply, he can solve the problem in the time necessary for him to make the simple mathematical calculations.

Because recognition-level thinking is used so widely in everyday life, pupils should be thoroughly acquainted with the techniques of using it and with its many shortcomings.

A third meaning of thinking is the thought processes involved in solving a problem. By problem, we mean a forked-road situation for which there may be several possible solutions; a situation which requires the collecting and weighing of evidence and the testing and making a choice among several possible solutions. This type of thinking is called reflective, scientific or reflection-level thinking.

An example is the thinking done by Mr. Jones in trying to start the "stalled" engine of his automobile. "Perhaps I have flooded the carburetor," he thought. So, before trying to start the engine again, he waited a few minutes to allow the surplus gasoline to drain from the carburetor. Again he tried, but without success. "What can be wrong?" he said to himself as various guesses (hypotheses) flashed into his mind. "Perhaps there is no gasoline in the tank," but upon looking at the gauge he saw that it showed the tank to be more than half full. He remembered too that he had just bought gasoline the day before.

"Perhaps there is something wrong with the ignition system; or maybe the feed line is clogged," he thought. Then he quickly "tested" the spark plugs and found they were firing so he ruled out the hypothesis that something was wrong with the ignition
system. To make sure there was gasoline in the tank he ran a stick into it and found it to be as the gauge indicated. On the basis of these data, he was satisfied that the feed line was clogged, because, if gasoline were getting from the tank to the cylinders then the spark would ignite it. All evidence pointed to one hypothesis. To test this hypothesis, Mr. Jones disconnected the feed line and pumped air into it with his tire pump until he heard the air bubbling through the gasoline in the tank. Then he knew the feed line was clear, so he reconnected it, climbed into his car, stepped on the starter and in a moment the engine started.

If we analyze this situation, we see that Mr. Jones was faced with a problem; a forked-road situation; an I-don't-know situation. Quickly several hypotheses, each a guess as to what might be wrong, came to his mind. Then he examined each hypothesis in terms of its consequences; that is, what each would mean in terms of steps necessary to start the engine. If the carburetor were flooded, the surplus gasoline would quickly drain out of it; but when the engine would not start after sitting long enough for this to happen, he ruled out this hypothesis. With this hypothesis eliminated he tested other likely hypotheses. As he did so, more data accumulated. Finally, he reached a point at which all the data seemed to point to one hypothesis. To test this hypothesis, he made sure that the feed line was clear and then he tried starting the motor. The result was that the motor started.
Then he knew that this hypothesis was the correct solution because it worked; it enabled him to start the engine.

Here we have a problem, hypotheses, data, test of hypotheses and choice of hypothesis. These are the earmarks of the complete act of reflection-level or scientific thinking.

The outstanding characteristics of scientific thinking, not characteristic of the other types of thinking, are that it carries within itself a method of discovering new knowledge and ways of knowing right from wrong. New knowledge is tested by experiment. Theories or hypotheses used to predict new knowledge must harmonize all pertinent data. In harmonizing data, the old and new are reconstructed in the light of each other. Reflection-level thinking is the only type that provides for reconstruction of experience which gives new meaning to experience and which increases the ability to direct subsequent experience.

Teaching which promotes reflection-level thinking is problem teaching. It brings pupils face to face with I-don't-know situations or forked-road situations which can be solved only by reflection-level thinking.

Right-answer teaching, whereby pupils are handed exercises and authoritative answers and are required to find the answers, is not problem teaching. Right-answer teaching involves a one-road situation. In science, it usually involves the application of a known principle. The thinking required is recognition-level thinking.
The Assumptions of Relativity Psychology. In this chapter, we see that the implications of relativity psychology for teaching are far reaching. But before considering them, let us state briefly the fundamental assumptions of relativity psychology. They are as follows:

(1) An organism is continuously acting and is continually seeking outlets for its activity. The organism and the environment, working cooperatively or jointly, initiate and direct the activity.

(2) All action is purposive; it is always directed toward a goal; it is continuously shaped and reshaped toward the accomplishment of a goal, in accordance with the psychological principle of least action.

(3) All action derives its peculiar characteristics from the individual's insights and from his knowledge of how to use his bodily structures, together with the objects of his environment, as means for accomplishing his ends.

(4) All action is unique—-it is always adjusted to the unique influential factors. These factors may be either personal or environmental.

(5) Every stimulus is a continually changing, directive factor; changing cooperatively with the responses of the organism as progress is made toward the goal; directive, in the sense of acting as a tool for achieving the goal.

(6) The action of an organism is continuous; an organized whole from beginning to end; not a series of separate
responses. The separate acts can only be interpreted in terms of the whole act—the goal, the organism's insights and the environment.

(7) Learning is the development of insight; it is discovery of relationships; it is the development of understanding and foresight, all of which increase control over future behavior; that is, it enables one to reach one's goal easier and quicker.

(8) To change behavior, change either one or any combination of, goal, insights or environment. Behavior can be predicted according to the psychological law of least action.

(9) Education is "...that reconstruction or reorganization of experience which adds to the meaning of experience, and which increases the ability to direct the course of subsequent experience."

**Implications of Relativity Psychology for Teaching Science.**

If a pupil's behavior is purposive, if he is inherently active, and if he is continually seeking outlets for his activity, then a teacher should capitalize these natural characteristics. That is, she should look to the natural interests of a pupil.

Interest, as used here does not mean attention gained by snapping one's fingers, by colorful enumeration of facts or by putting colored pictures in books. Here, interest is comparable to the attention of a football player in a game between two rival schools. What is the nature of such a situation?
Such a situation is problematical; there is an element of uncertainty; and there is more than one probable outcome. The player has something at stake; he anticipates the possible outcomes of the game and the consequences of each. The outcome may determine whether he makes a "letter"; whether he is chosen for the All American team; or whether the team will be the champion of the conference. The possible outcomes will affect the player's future life and are so important to him that he is emotionally aroused.

But a spectator in the stands, who knows little about the participating schools, who knows none of the players and who is indifferent to the outcome, has little interest in the game. Watching the game is merely a pleasant way of passing the time of day. The spectator anticipates no change in his future life, if one or the other team wins and emotionally he is unaroused.

"The word interest in its ordinary usage," says Dewey, "expresses (I) the whole state of active development (II) the objective results that are foreseen and wanted (III) the personal emotional inclination."20

"Soft" pedagogy and behaviorism have a tendency to isolate and exaggerate the second part. To secure attention, all subject matter is made easy, exciting and pleasurable. All school work is made pleasant and agreeable, and few,

if any, pupils are ever failed. "To keep a child happily adjusted to life is the paramount responsibility of both home and school." 21

Soft pedagogy is based mainly on the assumption that the end products of education are skills and subject matter, and that the end products are irrelevant to the normal activities and interests of pupils. The end products of education are assumed to be something which have to be acquired, so the common sense thing to do is to make the acquirement easy and pleasant; "sugar-coat" them.

During the "thirties" the soft pedagogues gained a firm foothold in American education. No doubt economic and social conditions were such as to promote the philosophy. From personal experience, we know that in many schools it is well nigh a crime if a teacher fails a pupil; and, we know too, that the general opinion today among editors of textbook companies is that a good textbook must be easy, it must be strikingly and beautifully illustrated and it must be "interestingly" written.

This tendency in textbooks is shown in several science textbooks published during the past few years. Seemingly, these books are not much more than picture books which glorify science and the scientific accomplishments of "big" business. Discussion in them is largely an enumeration of highly glorified facts.

The opposite extreme of the philosophy of soft pedagogy is the philosophy of discipline. According to this school of thought, what a pupil is taught is of little consequence as long as the material is difficult. Learning difficult material disciplines a pupil; it toughens him for hard work and the hard life that is ahead of him. If a pupil does not like to study difficult material on its own account, he should be forced, if need be, to study it.

The only way to avoid soft pedagogy on the one hand and the coercion of disciplinarians on the other is to make the study of subject matter purposeful. "When material has to be made interesting," says Dewey, "it signifies that as presented, it lacks connection with purposes..."22

A problem, as we have said, to be interesting must be purposeful and must involve doubt and confusion or conflict in the learner's mind. The outcome must be problematical; it must cause concern for the pupil. The pupil must be keenly aware that the outcome is going to make a difference in his future acting and thinking. An interesting problem causes a pupil to anticipate the various possible outcomes and what the various outcomes will mean to him. An example will explain what is meant.

As this is being written, Germany has just acquired control of a large share of continental Europe. As a result many questions have been raised in the minds of the American

22 Dewey, John, Education and Democracy, p. 150.
people. A few of them are: How will the domination of Europe by Hitler affect our markets? Will Hitler be satisfied with the territorial, political and economic gains that he has made to date, or will he soon try to conquer South America? If he tries to conquer South America what will the United States do?

Because Hitler's domination of Europe is likely to affect vital interests of the American people, they are trying to anticipate all lines of action that Hitler may take and the consequences of each line in order to devise a plan for offsetting them.

This problem is a forked-road situation and it has grown out of the interests of the American people. There are several possible solutions. To know what to do in each case can be determined only by reflection-level study.

Teaching which develops reflection-level thinking is called problem-solving teaching. Problem-solving teaching consists of two stages; the problem raising and problem solving stages. Miller and Blaydes give a fine example of the problem raising stage in describing how a teacher took advantage of pupil interest in a biology course.

It (the demonstration) consisted of a five-gallon bottle, or carboy, slightly more than half full of water. In the bottom were two inches of sand in which were anchored a few equatic plants. Floating in the water was a small amount of a filamentous alga. On the sides of the bottle were several small water snails and swimming about among the
plants was a small goldfish. A cork had been pressed tightly into the neck and covered with a heavy layer of melted paraffin.23

Here was a situation which aroused interest immediately; it was a problematic situation about which each pupil wanted to know the outcome. Each pupil wanted to know "How long the fish would live in the microcosm without food and fresh air?"

Of course, a teacher interested only in teaching facts would answer the question immediately and would thus kill all interest and spoil all the fun. But a teacher interested in solving problems and in developing reflection-level (scientific) thinking, would make little comment other than raise a few pertinent questions to assure mental confusion. Here is a situation with many teaching possibilities.

In most classes, this situation would cause pupils to speculate as to the probable outcome. No doubt, a few would say that the fish will live for weeks because it breathes water, not air. Some would say that the fish will die in a few days because there is no food in the microcosm for it to eat. Others would suggest that the fish can eat the plants or perhaps eat the snails. Others may contradict this statement. And still others may want to know whether the presence of the plants and snails will affect the length of time that the fish will live. For each question raised, several

23 Miller and Blaydes, Methods and Materials for Teaching Biological Sciences, p. 17.
hypotheses (probable answers) would be proposed. Testing these hypotheses calls for experiments. Experiments call for planning, organizing, observing, recording of data, judging, criticising and reaching conclusions.

Experiments also require that pupils understand the techniques of the scientific method. For example, suppose that a pupil wants to determine whether the presence of plants will affect the length of time the fish will live. This would necessitate a control and a situation whereby all factors affecting the life of the fish would be eliminated except the effect of the plants. Carrying out such an experiment would develop skills, attitudes and habits. However all would be done with a definite purpose.

Without doubt, out of this study would arise the question, "What is life, and what are the conditions necessary for living things to live?" This, no doubt, is the question that the teacher wanted to study.

Now, it should be clear that the teacher in such a situation is not manipulating stimuli to cause pupils to arrive at a set of preordained conclusions. The teacher is merely opening up a large area of study wherein pupils can delve and discover problems.

Instead of the teacher proposing a problem, the teacher "sets the stage" so that the pupils propose it. In this way the problem becomes the pupil's problem as well as the teacher's. And in solving it, subject matter and skills become a means
to an end; not ends in themselves. Subject matter and skills presented in this manner need not be glorified or sugar-coated because they are connected with purpose. As Dewey says, "It is only when materials are not connected with purpose that they need to be made interesting." And in solving problems by reflection-level study, the subject matter is not separated from method because the method of teaching is the method of obtaining new knowledge. Method is the means to new knowledge. When new and old are harmonized in the light of each other, they point to new ways of obtaining new knowledge. According to Dewey's definition, this is education.

A detailed explanation of methods of conducting a class, of the choice of subject matter, of the part played by the teacher and of other details cannot be made until we have studied the implications of democracy and science for teaching. These will be considered in the next two chapters.
CHAPTER IV

DEMOCRACY AND ITS IMPLICATIONS FOR TEACHING SCIENCE

Why Consider Democracy? We have already seen that a thing, in and of itself, has no meaning to a human mind. Only when relationships are sensed between a thing and other things does a thing have meaning. Also, we have seen that meaning changes as sensed relationships change. In one set of relationships, a thing may have one meaning; and in another set of relationships an entirely different meaning.

To Koehler's apes, a box in one configuration (set of relationships) mean something to stand upon; in another, something to lie upon. In a train which is moving at a uniform rate with respect to the track, the path of a falling ball appears, to an observer in the train, to be a straight line. To an observer outside the train, standing beside the track, the path appears to be a curved line (parabola). A change in sensed relationships is a change in meaning.

Then too, we have seen that the behavior of an organism may be affected by change of environment, change of goal, change of insight, or change of any combination of the three. Also we have seen that action can be interpreted, in a given environment, only when the goal of the organism is known. Unless the goal is known, action seems meaningless.

Since a teaching program is a plan of action, in order that the program may be definite and meaningful, it is necessary to know the aims (goals) of the program and the kind of social
organization (environment) in which that program is to function. And if the aims of the program are not to oppose the aims of the social organization, then it is necessary to know the aims of both. The importance of knowing goals as well as environment is shown in the following comment:

A World Congress on Education for Democracy was recently convened at Columbia University. Its various seminars, led by Teachers College professors, have rendered a report in which it is stated that education should be for citizenship, for economic life, for personal and family relations, for ethics and religion...the conferees were unwilling to commit themselves definitely except to insist that education is for democracy. But, what is democracy? At this point, these conferees, like the builders at Babel, found themselves speaking strange tongues.

The most startling single fact concerning America's educational Gargantua is this: those who guide and manipulate it have lost or mislaid their compass; they cannot agree on the goal for which the instrument is to be used.1

As long as the conferees did not define democracy, all the aims and objectives had little or no meaning. Probably Hitler, Mussolini and Stalin would sanction every one of the aims proposed. Stalin might object to religious training.

Bruce points out how senseless it is to set up objectives for a school program without defining the kind of social organization in which that program is supposed to function. He says

in writing of a group of teachers who were considering ob-
tectives for teaching:

...one might be an advocate of milit-
tary training in high schools, another
might be a believer in the dogmatic in-
stilling of internationalism or of
pacifism, a third might present the evi-
dence in favor of economic nationalism,
but all would be strong for "citizenship"
as an aim,...one emphasizing conformity
to old standards through the reading of
sacred books, a second using a set of
activities to correct personal traits
one at a time, and a third promoting a
socialized program stressing intelligent
co-operation.  

This well illustrates the confusion of thought in American
education today.

As has been said before (see p. 49), a choice of a social
organization or educational program cannot be made on the
basis of scientific facts alone. A choice of either depends
on a people's philosophy of life. It depends on the kind of
lives the people want to live; on how much responsibility
they want to assume in directing national and local affairs;
or whether they want to make choices and decide important is-
ues of life or want to turn such matters over to someone else.

The people of Germany chose Hitler and his program, rather
than a democratic program, because they were befuddled and
either did not want to take the trouble to decide the issues
which confronted them or felt entirely incapable of doing so.
Of course, Hitler believes the masses of people are "silly
sheep," incapable of shouldering the responsibilities of self
government and making decisions that need to be made.

Theoretically, there are three distinctly different forms of social organization: autocracy, democracy and anarchy (laissez-faireism or rugged individualism). Without doubt, most pupils, parents and teachers in the United States would say that they want a democratic social organization and a school program which is in keeping with democracy; a program that will enable children to understand democracy, that will enable them to participate in a democracy, that will enable them to further democracy and that allows democratic living to be practiced in school.

But, as has been pointed out, in order to set up such a program, it is necessary to formulate a careful, clear and usable definition of democracy; and to know the aims and basic assumptions of democracy. These assumptions and the definition of democracy should make up a part of the assumptions on which the program is based. The program should be thought of as an hypothesis that is to be tested in practice.

If experience with such a program proves that it is unworkable, then one should revamp it and try it in practice again. This process should be kept up until it is plainly seen that an educational program in keeping with the original basic assumptions and definition of democracy is not workable, or until a completely harmonized, workable, program is developed.

What are the Assumptions of Democracy? According to Merriam one of the most important assumptions of democracy is:

The essential dignity of man, the importance of protecting and cultivating his personality on a fraternal rather than on a differential
principle; and the elimination of special privilege based upon unwarranted or exaggerated interpretation of the human differentials. 3

According to the CYCLOPEDIA OF POLITICAL SCIENCE, one of the first advocates of the essential dignity of man and of the importance of protecting and developing each individual personality was Jesus Christ. At the time of His coming, the lot of the common people was very difficult. They were ignorant, highly superstitious, poorly fed, poorly clothed, poorly housed and many of them were diseased or were suffering from after-effects of disease. Most of them owned no property; they were either slaves or serfs, and were looked upon by members of the far less numerous upper class as an inherently inferior people. The masses had little or no opportunity to become educated and their hopes and ambitions were few. Most of their time and energy were spent keeping body and soul together; on the whole, they led a miserable existence.

When Christ came, he preached that man is sacred in his own eyes and sacred in the eyes of his fellowmen. Man has a free, responsible soul, fallen it is true, but God has revealed to man the mystery of his immortal destiny and has revealed to him how he may save his own soul. God made man the master of the destiny of his own soul; he is responsible for it. Christ preached that it is the moral duty of each to respect this responsibility, both in one's self and in others, and to help others develop such a sense of moral responsibility.

Furthermore, Christ taught that all the children of God are brothers, and all the sons of Adam are equal in their redemption. As a consequence, all slaves, serfs, tradesmen, beggars and lame and sick who accepted this philosophy, regarded themselves on par with kings and nobles inasmuch as they were subject to the same obligations to God. And they believed that their chances for a life hereafter were all equal. All were equal in the sight of God; birth counted for nothing; merit was everything.

This philosophy gave the masses hope; gave them a sense of direction and new goals; emphasized the importance of the human soul and the individual; and caused people to believe in themselves. It taught brotherhood, cooperation, equality and personal responsibility for one another.

When Christ preached this philosophy, the time and conditions were ripe for its acceptance by the masses. Consequently it spread like wild fire, and when the upper class tried to stamp it out by force, the persecuted became martyrs. This caused the doctrine to spread yet more rapidly. It swept over the Roman Empire and later over all of western Europe.

One would think that the dominance of this philosophy would have resulted in widespread freedom, accompanied by intellectual growth and social and economic reforms. But such was not the case.

Instead, about 300 A.D., the crumbling Roman Empire was overrun by Germanic tribes from the North, and each leader of
a tribe--a petty ruler called a feudal lord--set up a little kingdom or estate of his own.

On his estate or "manor" lived the peasants, tilling the soil, subject to the lord's control, and owing him "feudal dues." He was the overlord of the land, they were servile tenants... He was noble and privileged, they were common and unprivileged.¹

These petty rulers were easily "Christianized," accepting particularly the philosophy of the Roman Catholic Church; that they ruled by divine right. However, it was a second-hand right, derived from God through the Pope who, as representative of God on earth, possessed by divine right, authority over princes and feudal lords as well as over all other men.

The acceptance of this philosophy by the feudal lords and the common tie of faith among all the people enabled the leaders of the Church to establish a strong Church that, along with the feudal lords, ruled Europe until after the beginning of the sixteenth century. But, in order to insure unity of faith among its members, the Church ruled that all interpretations of the Bible should be made by priests, who were subject to bishops, who in turn were subject to the Pope.

...The Pope, who claimed to be the Vicar of Christ and as such to exercise divine authority. His voice was the voice of God, his decrees were laws intended by God for the government of men.²

The voice of God was considered to speak absolute truth and was not to be questioned either by serfs or lords.

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² Ibid., p. 31.
Religiously, the serfs were totally dependent upon the Church. Freedom of worship as one saw fit, and the right to make one's own interpretation of the Bible, did not exist. Few, if any, could read and even those who could found few Bibles available.

Economically, the serfs were dependent in every respect upon the feudal lord who owned the land. There was no way by which a serf could own land. If he did obtain possession of land, a feudal lord, with his band of soldiers in armor, was likely to take it from him.

Politically, the serfs had no rights. The right to rule was a divine right, vested in Church and feudal lord.

Within the Church, a thorough conflict developed between orthodox Christianity and the original teachings of Christ. The result was that the serfs, as far as the right to develop the human personality was concerned, were in worse condition than they were under Roman rule. So it appears that the right and opportunity to develop the human personality does not rest on the religious, economic and political rights which existed in Europe during the period from 300 to 1600 A.D.

As has been said, beginning about 1300 A.D., a new philosophy, opposed to the authoritarianism of the Church and of Aristotelian thought, began to emerge. And, too, several discoveries were made which showed Aristotle and the Church to be in error. Also several inventions were made which tended to loosen the strangle hold of Church and feudal lords on the serfs.
The invention of gun powder and fire arms was an important factor in breaking the economic hold of the feudal lords. The invention, in 1438, of moveable type by Gutenberg in Mainz, made possible the dissemination of knowledge at very low cost and contributed greatly to liberating men's minds from false superstitions and from false doctrines advocated by the Church.

Soon after the discovery of moveable type, Copernicus proposed the heliocentric theory of our planetary system, Columbus discovered the New World, and Magellan circumnavigated the globe. These discoveries cast doubt on the anthropocentric theory of the earth held by the Church, on the Pope's ability to reveal divine knowledge, on belief in his divine right to rule and direct the acts of men and on other teaching of Church and State. Perhaps at no time in the history of civilization, unless at the present time, has there been so much confusion of ideas as then.

All over Western Europe a growing sense of independence and freedom was springing up in the hearts of men. Martin Luther (1483-1546), leader of the Protestant Revolt, advocated the revolutionary idea that everyone should be taught to read so that he could make his own interpretation of the Bible. Others carried the idea further, and proposed that each individual should have the right to worship God as he pleased.

Naturally, there was much opposition to these radical ideas on the part of the leaders of Church and State. Such opposition is shown by the fact that, because of fear of persecution, Copernicus' heliocentric theory was not published
until his death. Galileo was called before the Pope, was forced to disclaim his radical theories and was confined in prison during the latter years of his life. Bruno, in 1600, was burned at the stake because he refused to disavow his belief in the heliocentric theory of the planetary system.

However, by the time of Newton, most of the antagonism against scientific investigation had died out. It had become evident that men were able by observation and experiment to discover new knowledge. Newton fired the imagination of his time, much as did Darwin and Christ in their times. Said Voltaire:

Very few people read Newton because it is necessary to be learned to understand him. But everybody talks about him.6

Becker says:

They were well aware that the great scientist had uncovered the secrets of Nature, and of Nature's God, in a way that to an earlier generation, might have seemed almost indiscreet. They were indoctrinated into the new philosophy through conversation, and through popular lectures and books which humanely omitted the mathematics of the Principia...7


6 "Lettres Philosophiques," XIV; Oeuvres (ed. 1879), XXII, 130.
7 Becker, Carl, The Declaration of Independence, p. 44.
The philosophy, as explained by its popularizers, is shown in
the following:

To describe the phenomena of nature, to explain their causes, to trace the re-
lation and dependence of these causes, and to inquire into the whole constitution of
the universe, is the business of Natural Philosophy. A strong curiosity has prompted
men in all times to study nature; every use-
ful art has some connection with this science;
and the inexhaustible beauty and variety of
things makes it even agreeable, new and
surprising.

But Natural Philosophy is subservient to
purposes of a higher kind, and is chiefly to
be valued as it lays a sure foundation for
Natural Religion and Moral Philosophy; by
leading us, in a satisfactory manner, to the
knowledge of the Author and Governor of the
universe...We are, from His works, to seek to
know God,...To study Nature is to study into
His workmanship; every new discovery opens up
to us a new part of His scheme...By proceed-
ing with due care, every age will add to the
common stock of knowledge; the mysteries that
still lie concealed in nature may be gradually
opened, arts will flourish and increase, man-
kind will improve, and appear more worthy of
their situation in the universe, as they ap-
proach more towards a perfect knowledge of
Nature...8

In other words, so the people believed, God said in effect
to mankind: I have created a world for you to learn about and
use. I have devised the world according to a plan; I have given
you a mind, capable of understanding that plan. That is all I
can do. Everything is up to you to make the best of what I have
devised. By looking to Nature, rather than to the Pope or the
head of the State, you may in time learn all about the universe
and its absolute laws and so in the end solve all your difficulties.

8 Maclaurin, C., An Account of Sir Isaac Newton's
Philosophical Discoveries, pp. 3, 4, 95.
Obviously, people of the eighteenth century did not cease to worship, although the object of their worship changed. Nature was deified; Nature became the new object of worship. Instead of God expressing his will through the Pope, He expressed it through His works; through Nature. Truth is, what is. In order to find truth—that is, to find invariable, everlasting absolute knowledge—look to Nature and discover what is. To interpret the universe, in this sense, was quite easy.

However, when government was considered, there was a hitch in the logic that what is, is right, for, presumably, God made both George III and also Sam Adams; yet how was one to know whether the acts of George III, who was tyrannical, or the acts of Sam Adams, who was very liberal, were in accord with the will of God and Laws of Nature?

Locke came to the rescue by proposing that since the will of God is revealed in Nature, one could find out what God willed governments to be and do by finding out what kind of governments men would enter into if they acted according to the natures which God had given them. Locke said:

What state all men are naturally in, and that is, a state of perfect freedom to order their actions and dispose of their possessions and persons, as they think fit, within the bounds of the laws of nature, without asking leave, or depending upon the leave of any other man. A state also of equality, wherein all powe and jurisdiction is reciprocal, no one having more than another.9

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9 Locke, John, Of Civil Government, Book II, Sec. 4 Works (ed. 1812)
This natural state is not a state of licence, but a state of freedom and equality. The only limitations to freedom were "the bounds of the law of nature." But what is this law of nature?

According to Locke, "...reason...is that law" and the law teaches all mankind who will but consult it, "that being all equal and independent, no one ought to harm another in his life, health, liberty or possessions..." These rights of men, stated in the law of reason, were believed to be the "inalienable rights of man."

But, suppose a few men violate the law of reason by refusing to act rationally. Then what? In this case, says Locke:

...the execution of the law of nature is...put into every man's hands, whereby every one has a right to punish the transgressor of the law,...but only...so far as calm reason and conscience dictate what is proportionate to his transgression.10

Instead of everyone trying to write and enforce the laws of government, Locke suggested that a few should be appointed to do this. But these few were to make only laws that afford health, liberty and safety of possessions. In turn, the people would agree to abide by the rules enacted as long as the rules made safe their lives, liberties and possessions or insured man his inalienable rights.

Men being, as has been said, all free equal and independent, no one can be put out of his estate and subjected to the political

10 Ibid., Sec. 8
power of another, without his consent. The only way, whereby any one divests himself of his liberty, and puts on the bonds of civil society, is by agreeing with other men to join and unite into a community, for their comfortable, safe and peaceable living, one amongst another, in a secure enjoyment of their properties, and a greater security against any, that are not of it...When any number of men have so consented to make one community or government, they are thereby presently incorporated, and make one body politic, wherein the majority have a right to act and conclude the rest.  

It was Locke who really proposed that governments exist for men, not men for governments, and that all governments derive their just powers from the consent of the governed. All authority comes from within; not from without.

Because the power to govern was granted by the governed, man's political destiny was placed in his own hands. Man now had a tool for governing himself and for solving his political and economic problems.

Locke's philosophy also granted the individual certain economic rights; the right to own property and to protect that property. Thus, one man would not have to be dependent upon another for food, shelter and clothing, as he was under Feudalism. Man's economic destiny was placed in his own hands. However, with these rights, went the responsibility of respecting these same rights of others.

Locke's philosophy placed man's political and economic destiny in his own hands; Newton's philosophy gave man a method

11 Ibid., Sec. 14.
of controlling or coping with his environment other than appealing to a divine authority through ceremony, prayer, fasting and sacrifices. The Christian religion, as proposed by Christ, Martin Luther and others, made man master of the destiny of his own soul and granted each the right to worship God according to the dictates of his own conscience. All three philosophies placed man at the center of things. Each was a tool that man could use in shaping and guiding his destiny.

Democracy, Protestantism, and Science all grew up together in a common soil. Each was a reaction against authoritarianism and dogmatism. Each taught the essential dignity of man and the importance of protecting and cultivating the human personality. Each made the individual responsible for his own acts. And each granted certain rights and privileges but taught that the individual should respect these same rights of others. Each provided within itself a way of knowing right from wrong. Outside authority was made unnecessary.

In Western Europe, due to persecution of those who held this general philosophy of government, science and religion, many fled to the New World, and it was here that the new philosophy of life had a chance to be put in operation.

It was Jefferson, in the Declaration of Independence, who really put the general philosophy of that time in concise terms:

We hold these truths to be self-evident: that all men are created equal; that they are endowed by their creator with certain inalienable rights; that among these are life, liberty and
the pursuit of happiness; that to secure these rights, governments are instituted among men deriving their just powers from the consent of the governed; that whenever any form of government becomes destructive of these ends, it is the right of the people to alter or abolish it.

**How Did the New Philosophy Work Out in the New World?**

Most students of political science agree with John Ise--economist, teacher and writer--who recently said in a speech before Kansas State College students that "the most democratic society that has ever existed in the life of man existed during the frontier days of the Middle West." What were the conditions that made this possible?

It is in the Middle West that the writer has lived most of his life, and it was in Jackson County, Kansas that his grandfathers homesteaded shortly after passage of the Homestead Act in 1862. The United States government gave (note gave) each of them 160 acres of fine land in return for living on it five years.

Both of them brought to Kansas their families, livestock, wagons, plows, axes and other tools and a few household necessities. After arriving, they built houses and barns out of logs cut from the timber which grew on their land, plowed the prairies and planted crops. They raised hogs, cattle, sheep, horses, wheat, corn, cane, oats, fruits and vegetables. Later they helped build churches and schools.

Their sheep supplied them with meat and with wool from which they made most of their clothes. Their cattle supplied
them with milk, butter, cheese and with hides for making shoes and clothes. Their hogs supplied them with meat and with fat for cooking and making soap. Their wheat and corn supplied feed for livestock and flour and cornmeal for the people. Cane supplied sorghum and brown sugar, their only source of sugar.

Surplus meat, cattle, hogs, corn, wheat and other commodities were usually exchanged (bartered), if possible, for tools, salt, coffee, glass, gingham, shoes or a subscription for the town weekly newspaper. The principal motive for production was home consumption; not profit.

Economically, the community was almost self-sufficient. Farmer, lawyer, merchant, shoemaker, doctor and blacksmith labored in an economy of home production and consumption which was tempered by neighborliness and a sense of civic duty. The shoemaker took care not to make a bad pair of shoes because he expected to see the wearer of them at church, and the farmer dared not sell spoiled eggs because he might meet the buyer on the street. The politician took thought about the laws that he proposed in the legislature because his proposals were often reviewed at the next town meeting where each citizen expressed his candid opinion, if he cared to do so, on any problem that faced the community or nation. And, each citizen did so without fear of being imprisoned, fined, losing his job, or having a mortgage foreclosed on his homestead.

Government was instituted by the people, for the people. Government was a tool which people used to instrument their
own collective welfare and to shape their collective destiny. Government was by the majority. The majority will was determined by ballot.

Success of each individual was dependent largely upon his health, how hard he worked, the weather and a certain amount of foresight and luck. There was little competition among the citizens of a community, except to see who could raise the best crop or best livestock. They did not battle each other for food, clothing and jobs. Their main struggle was with the elements; not with each other. Their society was one of live and let live.

Freedom of speech, freedom of press, freedom of worship, free education, and equal right and opportunity to own property were considered inalienable rights. Each was his own boss, made his own choices and decisions and was personally responsible for his own acts. Each believed himself to be master of his own destiny and his own soul.

Because of the environment, individual resourcefulness and independent action had to be developed on the part of each individual; else he would have perished. Limited governmental action, together with the laissez-faire principle in economics, were well suited to frontier life and to rapid development of natural resources. Because people were economically independent, the freedom of one seldom interfered with the freedom of another.

If we analyze the conditions that made this democratic life possible, we find that the people:
1. Owned their own homes and farms, free from mortgage debt.
2. Owned their own means of production for supplying most of their wants, and produced most of the raw materials which they needed to supply these wants.
3. Governed themselves. Their government was for the people and by the people. Important questions were decided by majority vote.
4. Were all about equal, economically, culturally and in most other respects. No single minority group had an advantage in way of control of money, land, education, government, raw materials, means of production or other vital needs.
5. Each had a sense of responsibility to himself, to his family and to his community, which made for a cooperative spirit of live and let live.

In this early frontier society there was no distinct owner class, labor class and consumer class, each with divergent interests. The owner did his own labor and consumed most of the goods that he produced. Hence, the interests of owner, laborer and consumer were the same.

Because the people were all about equal educationally, culturally, economically and politically, there were no distinct classes caused by differences in these respects. Moreover, because of equal opportunity for each to participate and of wide-spread participation in cultural, educational and political activities, there was little tendency for inequality
to develop in these respects. Free land, free schools, free press, free speech, free ballot and freedom of religion made for equality of opportunity for each to participate in a wide area of interests that were mutually shared.

Democracy Defined. Bode, Bruce, Bayles and others have defined democracy as "a form of social organization which provides equality of opportunity to participate in a growing area of interests mutually shared." Perhaps a few illustrations are needed to explain what is meant.

In Central Park, which is located in the heart of New York City, a bridle path is maintained at public expense where any resident of the city may ride his horse free of charge. On first thought, this public venture seems very democratic. But, the catch is that only a very few people can afford to own and keep a horse. The economic status of the people rules out equality of opportunity, except for a very small minority which is doubtless decreasing. In no respect is this venture, according to our definition of democracy, democratic. Let us consider another example.

No doubt, anyone who frequented Chicago or any other large city during the latter part of the 1920's saw the confusion of late-afternoon week-day traffic. An attempt to remedy the confusion might have taken several courses.

First, the streets could have been kept as they were and each pedestrian and each driver of a motor vehicle could have been allowed to go where he wanted by any means that he desired to use. For example, a truck driver could have equipped his
truck on four sides with steel bumpers and could have driven through the streets knocking to the right or left everything that got in his way. The truck driver would have been a "rugged individualist" of the highways. He would have been a law unto himself.

Second, the streets could have been kept as they were, and strict laws passed with the consent of a small but powerful minority, reducing speed to a "snail's pace" for everyone except the privileged few who were responsible for passage of the laws.

Third, the streets could have been kept as they were and all cars and trucks could have been kept off. Only horse-drawn vehicles might have been allowed. This line of action would have meant going back to the good old days, the horse-and-buggy days. Either of these last two lines of action would have been the conservative solution of either going back to the good old days or maintaining the status quo.

The fourth line of action would have been to widen the streets, round off the corners, speed up traffic, build underground railways to take the place of buses and street cars, build overpasses at the busiest intersections and require by law (passed by consent of a majority of the people) that all pedestrians and drivers of motor vehicles cross streets at designated times.

At first glance, the first line of action appears to be democratic; but the fact that only those who might own armored trucks would be safe on the streets would limit greatly the
number who would use the streets. The second and third are likewise undemocratic because they too decrease the number who may use the streets, and provide no way to increase the number.

The fourth line of action not only provides equal opportunity, but actually increases such opportunity manyfold by decreasing traffic hazards and increasing efficiency. This action is democratic; it is one of live and let live; it really provides equal opportunity for a large majority of the people "to participate in a growing area of interests mutually shared," and does not grant special privilege to any group.

The traffic problem is one which, in most states, is being solved in the light of modern needs, modern methods and modern conditions, to the benefit of the many instead of the few.

**What Democracy is Not.** From the standpoint of the relativists, it is just as important to know what democracy is not as to know what it is. Theoretically, as has been mentioned, there are three basic forms of social organization: autocracy, democracy and anarchy (laissez faireism).

In an autocracy, the masses are governed usually by a small minority which derives its right to govern from some agency outside of the body governed. For example, the right may be derived from a supreme Being, from divine right of birth, from an unchangeable, outmoded constitution or from sheer force. The rulers have many privileges; the ruled have few.

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*We recognize, of course, that there may be, as under stress of war, a condition of autocracy by a majority, wherein minorities are not permitted to voice their own opinions.*
Freedom for individuals is limited and unequal. The governed are responsible to the government, but the government is not responsible to the governed.

In an anarchy, theoretically, each individual is a law unto himself. Each does what he pleases or is big enough and clever enough to do. There is no governing body. Freedom for the individual is unlimited. Each is responsible only to himself.

In a democracy, as has been said, the right to govern is granted by the governed. Authority comes from within the group governed; not from without. Freedom is limited and equal. Responsibility is shared equally among the members of the group. The individual owes certain responsibility to the group and the group owes certain responsibility to the individual. For a member of the majority, there is no conflict between the individual and the government or State. A member of the minority may not agree with the majority, but he has the right to influence members of the majority to join the minority. In this way a minority may become a majority.

Democracy is not, as many misinformed people believe, a mixture of, or a compromise between anarchy and autocracy, any more than science is a compromise between idealism and materialism. True, democracy resolves the dualism between anarchy and autocracy, but there is as much difference between either of these and democracy as there is between autocracy and anarchy. Being democratic is not oscillating back and forth between autocracy and anarchy.
That democracy is not a mixture of autocracy and anarchy is very difficult for many to understand, especially for some educators. Even Kilpatrick, who is a devout proponent of democracy, does not seem to understand this fact. The writer has heard him say, in effect, that pupils should be surrounded with tools, books and other materials and then each should be allowed to choose and do what he wants to do. The duty of the teacher is to assist the pupil. However, in case the teacher sees that pupils are not mastering the fundamental skills and subject matter, time should be taken out for drill and study of these particulars.

For Kilpatrick, democracy amounts to doing what the pupil wants to do part of the time (anarchy), and then having pupils do what the teacher wants them to do the rest of the time (autocracy).

Kilpatrick's whole difficulty is that, as far as the pupils are concerned, there is no relationship between his means and his ends; that is, there is little or no relationship between method of teaching and subject matter. Perhaps an illustration will explain what is meant.

Science is sometimes defined as a method of obtaining new knowledge. In other words, a scientist organizes knowledge for the purpose of formulating hypotheses which can be used to predict new knowledge. This new knowledge (skills and subject matter) is then used to acquire more new knowledge, which in turn is used again and again. Thus the method enhances the
knowledge and the enhanced knowledge in turn enhances the method. Method (means) and knowledge (ends) are made one; they are inseparable; the means and the ends work together hand in hand; the means do not defeat the ends.

The organization of knowledge to obtain new knowledge involves scientific or reflection-level thinking. In trying to harmonize new and old knowledge in solving one problem, several more are sure to arise. New problems, growing out of old ones, insure a continuity of development. This must be the case, says Dewey, for study to be interesting, and is necessary for the promotion of scientific thought.

According to Kilpatrick's plan, there is little or no continuity of subject matter. A pupil may study butterflies this week and Greek culture next. As a result, except by accident, what is studied this week will not enhance the skills learned last, or contribute to those of next.

Kilpatrick is a firm believer in reflection-level study, but, because of discontinuity in subject matter, method and subject matter do not support each other materially. For this reason, Kilpatrick must separate subject matter and method in order that pupils may learn the fundamentals. As a result, classroom procedures must oscillate between anarchy and autocracy; consequently, his methods defeat his democratic ends.

Another outstanding misconception of democracy is that it means weak governmental control. The results of lack of such control are shown in the follow example:
Shortly after the discovery of sulfanilamide, many medical doctors asked drug manufacturers to compound this drug in such forms that it could be given to patients intravenously. In 1938, a drug company put it on the market in dissolved form, but without having first tested its effects on human beings or other animals. The use of this compound resulted in the death of 67 people.

Probably, had it not been for the quick and efficient action of the Federal Food and Drugs Administration in tracing the sale of the drug and stopping its use, several hundred people would have been killed. But the sad part of the whole affair, other than the 67 deaths, was that the officers of the Food and Drugs Administration could legally stop the sale of the product only because it was mislabeled and not because it was dangerous to human health.

Seemingly, the death of 67 people in the United States, caused largely by a drug company's desire to reap the profits that would accrue from being the first to put this product on the market, was not news, because comparatively little was said about it in the metropolitan newspapers.

Governmental control, which does not protect the general welfare of its people, does not provide equal opportunity for all to participate in a growing area of interests and is therefore undemocratic.

Too often democracy is confused with anarchy; especially, is this true with respect to individual freedom. As a result, democratic proposals are often opposed because they interfere
with personal liberty or freedom. Few, if any, will say that requiring drivers of automobiles to stop at stop signs is undemocratic, even though it interferes with personal liberty. Fewer still object to city zoning, even though it interferes with property rights. However, many say that the program of the Tennessee Valley Authority, which has lowered the cost of electricity and has increased greatly its use, is undemocratic because the property rights of a few individuals are restricted. Restriction of property rights is not undemocratic as long as the restrictions are passed by democratic processes and are applied equally to all. Even though democracy has been in operation for more than 150 years in the United States, and civics, citizenship and government are taught in our schools, very few seem to have a clear idea of what democracy means.

Before going further with this discussion, let us take a look at the community in Jackson County, Kansas, and the country as a whole, in order to see how the democratic Utopia, which was started by our forefathers, has worked out.

How the Democratic Utopia of our Forefathers has Worked Out. During the frontier days of the Middle West, between 1870 and 1890, rapid changes in the nation as a whole were beginning to take place. But it was not until the coming of the twentieth century that Jackson County, Kansas was affected and began to grow up.

Today, the old north and south wagon road through Holton, the county seat, is an international highway--US Highway 75--
connecting Canada and Mexico. The store fronts around the
court house square have a coat of brighter paint, and are
lighted with neon lights instead of the coal oil lamps of
early days. The names on the store fronts in the best busin-
ess locations have changed too. Instead of such names as
Jones, Smith and Brown, as was the case twenty years ago, one
now finds such names as J. C. Penney and Co., Atlantic and
Pacific Tea Co. and Safeway Stores. Most of the stores now
run by the Browns, Joneses and Smiths are on the outskirts of
the business district or in residential districts where only
a limited number of customers are served.

But let us take a look at the status of the farmers in
Jackson County during the period 1930-1935. According to the
United States Census, we find:

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,588</td>
<td>Farms in 1935.</td>
</tr>
<tr>
<td>2,446</td>
<td>Farm operators consisting of tenants, owners and hired managers in 1935.</td>
</tr>
<tr>
<td>1,143</td>
<td>Tenants in 1935.</td>
</tr>
<tr>
<td>16</td>
<td>Hired managers in 1935.</td>
</tr>
<tr>
<td>973</td>
<td>Owners in 1935.</td>
</tr>
<tr>
<td>456</td>
<td>Part owners and part tenants.</td>
</tr>
<tr>
<td>57.9%</td>
<td>Of the farms mortgaged in 1930.</td>
</tr>
<tr>
<td>$10,728</td>
<td>Average value of the farms in 1930.</td>
</tr>
<tr>
<td>$6,534</td>
<td>Average value of the farms in 1935.</td>
</tr>
<tr>
<td>$4291.20</td>
<td>Average value of the mortgage debt in 1930.</td>
</tr>
</tbody>
</table>

If we assume that the average value of the mortgage debt and
the per cent of farms mortgaged were the same in 1935 as they
were in 1930, then by simple calculations we find that in 1935:

*Data not available for 1935.*
16% of the farm operators actually owned farms, free from mortgage debt.
47% of the farm operators were tenants.
23% of the farm operators owned mortgaged farms on which the average mortgage debt was 65% of the average value.
18% of the farm operators were part owner and part tenant.

Thus, in 1935 only a small minority of the farm operators actually owned the farms they operated. Approximately 50% did not own any land at all, and 23% owned farms on which the average mortgage debt was more than 65% of the value.

Of this 23%, no doubt many were paying more taxes and interest on the mortgage debt than the farm would have rented for.

Hence, it is safe to say that at least 60% of the farmers in Jackson County, Kansas, had a status equivalent to that of a tenant. And without question, this figure is low in comparison with the United States as a whole. According to Fortune Magazine\(^{12}\), in DeWitt County, Illinois, one of the best agricultural counties in that agricultural state, 75% of the farmers in 1940 were tenants.

According to the United States Bureau of Census, in 60 large cities in 1935, 39.3% of the homes were owner-occupied and in the nation as a whole less than 30% of the laborers, who had families, owned homes. Without doubt few such homes were free from mortgage debt. But this is not the worst.

According to a recent poll conducted by Fortune Magazine\(^{13}\), 23% of all the families in the United

\(^{12}\) Fortune Magazine, June 1940, Vol. XXI, No. 5, p. 84.
\(^{13}\) Fortune Magazine, February 1940, Vol. XXI, No. 2, p. 94.
States own nothing to speak of. Seemingly, the economic status, in terms of ownership of property, of quite a share of our people is not very high.

But what about the production, and control of production, of necessities used in Jackson County, Kansas? As an example, let us consider shoes.

Most of the shoes used are made in St. Louis, Mo. The hides (leather) from which they are made probably come from cattle grown in Texas, Colorado, Kansas or some other middle western state. The metal in the eyelets and on the tips of the strings is probably refined from iron ore mined in Michigan and cotton in the strings and linings may be raised in Georgia, Mississippi, Alabama or some other southern state. If the soles are rubber or paper (as is sometimes the case), then the raw products of which they are made may come from the other side of the world.

In preparing, assembling and processing the raw materials, and in manufacturing and distributing the finished shoes, thousands of people are directly and indirectly involved. In a shoe factory, likely there are more than two hundred people involved in making a pair of shoes. No one worker by himself can make a pair of shoes. Each runs a machine that does a particular job; all of these machines and their operators are required to make one pair of shoes.

But who owns the factory? Do the workers? Do the consumers? Or does someone other than workers and consumers? Who
manages the factory? Do the workers? Does a representative appointed by the workers? Do the consumers? Or does someone other than consumers and workers?

Berle partly answers the question, in discussing the 200 largest corporations in America, when he explains who furnishes the necessities for the every-day living of an individual:

The aluminum of his kitchen utensils by the Aluminum Co. of America. His electric refrigerator may be the product of General Motors Co., or of one of the two great electric equipment companies, General Electric and Westinghouse Electric. The chances are that the Crane Company has supplied his plumbing fixtures, the American Radiator and Standard Sanitary Corp. his heating equipment. He probably buys at least some of his groceries from the Great Atlantic and Pacific Tea Co.—a company that expected to sell one-eighth of all the groceries in the country in 1930...The cans which contain his groceries may well have been made by the American Can Company; his sugar has been refined by one of the major companies, his meat has probably been prepared by Swift, Armour or Wilson, his crackers put up by the National Biscuit Co. The newspaper which comes to his door may be printed on International Paper Company paper or on that of the Crown Zellerbach Corporation; his shoes may be one of the International Shoe Company's makes; if he seeks amusement through a radio, he will almost of necessity use a set made under a license of the Radio Corporation of America. When he steps out to the movies, he will probably see a Paramount, Fox or Warner Brothers picture (taken on an Eastman Kodak film) at a theatre controlled by one of these producing groups. No matter which of the alluring cigarette advertisements he succumbs to, he is almost sure to find himself smoking one of the many brands put out by the "big four" tobacco companies, and he probably stops to buy them at the United Cigar store on the corner.14

Berle further answers the question, in writing of the corporations in America in 1929, when he says:

Yet 200 of these or less than seven hundredths of one per cent, control nearly half the corporate wealth... It must further be remembered that the influence of these huge companies extends far beyond the assets under its direct control... In many cases the continued prosperity of the smaller company depends on the favor of the larger and almost inevitably the interests of the latter become the interests of the former... This concentration is made even more significant when it is recalled that as a result of it, approximately 2,000 individuals out of a population of one hundred twenty-five million are in a position to control and direct half of industry.  

Everywhere we look, we see that ownership of property and of raw materials and of the means of producing goods are becoming more and more in control of a small minority and that larger and larger numbers of people are becoming dependent for a livelihood upon this minority group.

As a result of the concentration of wealth, our economic system has become highly collectivized, and the average individual has lost virtually all control over the means of production and distribution of goods. In a country where the people do not own the homes, farms, mines, factories and market places, they cannot control the economic system in any significant degree except indirectly through government. As a result of such conditions, the economic power of a few of our industrialists far surpasses the economic power of any feudal lord.

15 Ibid., pp. 32-33.
As a consequence, those inalienable rights, which our forefathers cherished, enjoyed and fought for, are passing out of existence. A worker on an assembly line, who speaks his mind concerning wages and working conditions which affect his welfare, is likely to find his pay check waiting for him at the end of the week, and he and his family can choose between starving and going on relief; unless he is fortunate enough to find another job, doubtless as precarious as the former.

As this is being written, France has just capitulated to Germany. One of the several reasons given in the American newspapers for the ineffectiveness of the French army is that many Frenchmen did not care who won the war. Most of the French soldiers had nothing at stake. They owned no land, no homes and had little or no control over economic and political forces that seemed to be controlled by about one hundred wealthy families. "How could one be much worse off under Hitler?" the French soldier asked. "Why risk one's life for the little difference that might exist?"

And, too, the wealthy people of France did not seem to care. Apparently most of them were more afraid of losing their wealth, through social revolution if they won, than they were of losing it if Germany won. Hitler, they believed, would allow them to keep some of their wealth and at the same time help keep down social revolution. Democracy in France did not collapse because of pressure from without; it collapsed because of "dry rot" within.
The capitulation of France, the downfall of democracy in Spain and the bungling of internal affairs in Great Britain during the pre-war days, should be a valuable lesson for the United States, providing we wish to keep the democracy we now have.

Unless people can participate in the benefits of democracy, democracy does not exist for them. For democracy to survive, people must have a stake in it; and this stake must be more than the opportunity of scratching the ballot on election day for either tweedle-dee or tweedle-dum.

My grandfathers had a stake in democracy. Although they started with very little, before they died, each of them had a fine farm well stocked with livestock, a fine house, a barn and outbuildings, all free of mortgage debt. The outcome of democracy meant something to them. It meant a way of life; a way of living which they had a part in making and maintaining.

But what kind of a stake does one of the 23 per cent, who are totally dispossessed, have in democracy? To what can he look forward, other than to a relief check to keep body and soul together? In a democracy, such people should be able to do something about their plight. Opportunity should be provided so that such people can take part in working out their own destiny. With the aid of modern machinery and with the contributions of science of the past fifty years, providing such opportunities should be much easier than it was two generations ago.
Although the future for democracy externally and internally, looks dark, there are still reasons for hope. We still have public schools which furnish equal opportunity for a large majority of our people to get an education, even though most schools are not administered so that pupils may live the democratic life and learn to carry on in a democracy.

Then too, we have our public highways, public parks, public swimming pools, governmental owned and operated power plants, public libraries, public art galleries, churches and consumer cooperatives, all of which provide equal opportunities for participating in a growing area of interests, and which are moves in the direction of putting ownership and control of wealth back in the hands of the masses of people. Then too, there are labor unions and other organizations which increase the economic and political power of the masses and thereby offset some of the economic and political power of the lords of industry.

However, labor unions and other such organizations can be as tyrannical as any dictatorship if they are not designed, organized and administered to achieve democratic ends.

Implications of Democracy for Teaching Science. From the previous discussion, it has been seen that democracy is a means to an end; it is a tool for bringing about a way of life which in turn furthers and expands that way of life. Democracy is like a self-sharpening tool; the more it is used, the sharper it gets. The more democracy is put in practice, the more possibilities there are for it to be practiced. Democracy is
dynamic, ever expanding, ever evolving and ever growing. It is an evolutionary process; not revolutionary.

Democracy is based on two assumptions: (a) that human dignity and human personality are of the utmost importance; and (b) that a large majority of adults are capable of planning their individual destinies, and, through collective action, are capable of carrying their plans forward to completion. Human behavior is purposive; not mechanical and non-purposive.

For democracy to mean anything to the masses of people, these masses must be able to plan and shape their own destinies and carry them to completion. To do this, they must have the means, and control over the means, for doing so.

Since democracy is a tool, a means to an end, then the main implication of democracy for teaching is that we should develop pupils who can use this tool. But how is this to be done? The answer is, teach pupils to use this tool.

Since a democracy is evolving, dynamic, evolutionary and ever changing, it means that the problems of democracy are changing. Each day evokes new problems and requires new judgments. The important problems in a democracy are the ones which grow out of the lives of the people. They are the problems which need to be solved, so that the peoples' areas of interests may continually grow and opportunities for participating may be kept equal. Such problems are forked-road situations. They can be solved only by scientific (reflection-level) study.
As a consequence, the main implication of democracy for the teaching of science is the development of independent learners; that is, the development of pupils who are disposed to, and can, solve problems by the method of science.

This means that a teacher must start with the problems of the child; the conflicts in the child's outlook on life. These are problematic situations whose solutions, whether solved one way or another, are of importance to the child. It means that teacher and pupils must work together, making a scientific study of these problems; planning methods of attack, gathering and organizing data, formulating hypotheses, testing hypotheses, drawing conclusions.

As problems are solved in this manner, one problem grows out of another. This insures continuity of subject matter. The continual reorganization of subject matter, the formulating of hypotheses, and the testing of these hypotheses, result in enhancement and harmonization of a pupil's outlook on life. And thereby, the child's experience is continually reconstructed in such a way as to increase ability to direct the course of subsequent experience.
CHAPTER V

SCIENCE AND ITS IMPLICATIONS FOR THE TEACHING OF SCIENCE

What Does it Mean to Know Science? According to Encyclopedia Britannica, "Science is ordered, natural phenomena and relations between them." In other words, science is a body of organized, related facts and principles.

Two different interpretations of what it means to know science have grown out of the above definition. The first is that one must know the facts of science. These include the principles, stated more or less as facts. The second is that one must understand the principles of science and habitually apply them when the "proper" situations arise.

Another definition of science is that "Science is a method of obtaining knowledge, testing it, and organizing it for the purpose of obtaining further knowledge." Out of this definition has grown a third interpretation of what it means to know science. This interpretation is that to know science, one must know the method of obtaining knowledge, testing it, and organizing it for the purpose of obtaining further knowledge.

The first interpretation of what it means to know science emphasizes knowing scientific facts. The second emphasizes understanding of and ability to apply scientific principles. The third emphasizes the method of obtaining scientific facts and principles. In this chapter we shall discuss these three interpretations and the implications of each for teaching science.
Implications of "To Know Science is to Know the Facts of Science." If to know science is to know organized scientific facts, then the teaching of science is largely the promotion of mastery of these facts. This can be done by lectures, movies, demonstrations, class excursions, pupil "experiments" and study of textbooks.

For a pupil, the important thing is to learn science subject matter; that is, learn the factual end products or outcomes of science. Subject matter, not the pupil occupies the center of the stage.

Testing is a matter of determining the degree of mastery. This can be done by finding out how well each pupil can reproduce science subject matter, either orally or in writing.

Pupil interest and purpose, if considered at all, are secondary in importance; not primary. It may be wise for the teacher and the authors of science textbooks to interest a pupil in learning the subject matter, but if this cannot be done the pupil should be induced, by the teacher, to learn by other means; perhaps by extraneous means such as punishments or rewards.

Since knowing factual knowledge is the outcome of education, learning is largely memorizing facts. Thinking is largely the recollection-level type; memory. The development of independent learners, if it occurs, is in spite of the method rather than because of it. Thus the aims of teaching would not be in keeping with the aims of education for democracy.
The Implication of "To Know Science is to Understand Scientific Principles and Habitually Apply Them." Henry C. Morrison was the first to propose a systematic philosophy of science education based on the idea that to know science is to understand the principles of science and apply them habitually whenever the proper situations arise.

According to Morrison: "The teaching process throughout the secondary period is concerned with putting the pupil in adjustment with the world in which he must live and generating in him adaptability to a constantly changing world."¹

Adjustments with the world Morrison calls personality adaptations, and these are "always either attitudes or acquired abilities."²

"The adaptation," says Morrison, "is a unitary thing and the pupil has either attained it or has not... The ultimate test of... a genuine adaptation is that it is not lost, otherwise than through its transformation into new adaptations or through the rise of pathological inhibitions. It is never lost by simply fading out."³

The essence of an adaptation is that it represents a change in the organism itself. For example, one who has really come to understand the principle of natural selection "has acquired a new attitude toward the world in which he lives. He does not and cannot react to nature as he did before."⁴

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² Ibid., p. 19.
³ Ibid., p. 21-22 (1931).
⁴ Ibid., p. 17.
To bring about personality adaptations—the end products of education—Morrison organizes subject matter into learning units. He defines a learning unit in general as:

A comprehensive and significant aspect of the environment, of an organized science, of an art, or of conduct, which being learned results in an adaptation in personality.8

The unit in science is "a comprehensive and significant principle or complex of principles..."6 "The critical test of a unit in the science type is, does it tend to contribute understanding rather than a descriptive account?...Now an understanding, an insight, is in its nature a behavior pattern..."7

But what is a behavior pattern, other than a habit? Bayles, who substituted "habit" for personality adaptation" in almost every place that the latter term occurred in "Practice of Teaching in the Secondary School," found that in no instance was the meaning changed, and concluded that a "personality adaptation is merely a high sounding name for our old friend HABIT."8 In other words, a personality adaptation in science is an understanding of a scientific principle and a more or less fixed habit of applying the principle. Not only does Morrison believe that a personality adaptation is not lost; he also believes that the principles of science are unchanging (absolute) as far as pupils are concerned. He says:

5 Ibid., p. 24-25.
7 Ibid, p. 197.
During a full century past, however, discoveries in science which have been of such a character fundamentally to affect the outlook on life and the methods of thinking of the educated non-professional man can be counted on the fingers of the two hands and probably on those of one hand.9

Apparently, Morrison believes that science education is the fixing of personality adaptations most of which will require little or no modification during a pupil's lifetime.

How the personality adaptations and the units of subject matter are to be chosen is indicated by the following:

The teacher himself, or a group of teachers organized for the purpose, thoroughly grounded in the unit principle and well equipped with the academic content of the course, is the proper agency for working out the unitary course organization.10

From this statement, we see that Morrison makes no attempt to capitalize a pupil's natural interest. Morrison says, "We hate to learn." For this reason pupils must be motivated.

Motivation is the purposeful establishment on the part of the teacher and the school of a drive toward learning the specific objectives in hand.11

For some pupils, learning may be agreeable, and for others, disagreeable. However, no matter how disagreeable learning is:

Somebody, either parent or teacher, has to constrain and compel the pupil to the point at which this adaptation takes place. The pupil must learn this conduct attitude as truly as he learns a unit in arithmetic or one in geography as truly as he must learn to read.12

Bringing about preordained personality adaptations seems to be Morrison's major objective. If it cannot be done by making learning attractive, it must be done by coercion.

Morrison's formula for developing personality adaptations is the mastery formula--pretest, teach, test the result, adapt procedure and test again to the point of learning. Teaching science type units is done in five steps: exploration, presentation, assimilation, organization and recitation.

During the presentation (story of the unit) which occurs early in a unit, a pupil not only learns what the unit is about, but he also learns the outcome of the unit. The unit is in no way problematical; it is a one-road situation. Problematical situations, in which pupils predict probable outcomes and test their predictions by experiment, are not considered.

Although the situations are not problematical, Morrison makes study purposeful. He motivates a pupil, either by coercion or by other methods, to learn and understand a particular scientific principle and habitually apply it. In teaching, guide sheets are used which include leading questions, references for study, experiments and exercises, all of which are arranged and taught in order to establish the personality adaptation.

Experiments are used only to prove and help pupils understand and apply principles. They are not used to test predictions. Experiments, or data, which conflict with the principle
that is being taught are omitted. All materials are marshalled for one purpose only. In science it is possible, says Morrison, "to set up a definite goal and to attain that goal through a somewhat definite procedure and with the use of intelligently selected body of materials." 13

Thinking, necessary to master the unit, is largely confined to the mental processes necessary to follow the logic of the guide sheet and apply the principle to the solution of the exercises. Recognition-level thinking is the dominant type.

Testing is largely for the purpose of determining whether a pupil understands and can automatically apply the principles of science.

Since all learning for Morrison, as for the behaviorists in general, is fixing habits, he must, in order to be logical, deny that reflection-level thinking is different from any other fixed habit. Morrison says: "The scientific attitude of mind which we certainly associate with the study of science is nevertheless a specific habit." 13

Developing reflection-level (scientific) thinking, for Morrison, is just as simple as developing the habit of applying Boyle's Law or learning to handle Bunsen burner and test tubes. It can be done by teaching the proper unit. If the unit is mastered, the scientific attitude and habit of solving problems by the method of science, presumably, will be fixed for life. His method is engagingly simple. But let us scrutinize it more closely.

13 Morrison, Henry C., The Practice of Teaching in the Secondary Schools, p. 212 (1931)
As has been seen, Morrison's scheme is to have the teacher or some other authority select a group of preordained attitudes, skills and habits which pupils are to be taught.

If a pupil is interested in learning what is selected, all is well and good. If he is not, then the teacher must motivate the pupil, by force if necessary, to learn. All subject matter is marshalled into units, one-road situations, so as to bring about personality adaptations. The whole scheme is as authoritarian, dogmatic and dictatorial as any scheme that would be concocted in Nazi Germany for teaching German youths the Nazi philosophy.

For some reason or other, Morrison seems never to have learned that science is in opposition to dogmatism and authoritarianism, and that science is independent of externally imposed authority. Consequently, Morrison is unable to see that his method of teaching is in opposition to the method of science and defeats his efforts to develop the scientific attitude. His means defeat his purpose.

Developing scientific thinking by Morrison's scheme is very much like trying to develop the democratic way of life by indoctrinating people with democracy, but never allowing them to live it—a method used in most schools today. Twenty years ago, the Union of Soviet Socialist Republics claimed it was going to bring about democracy by first establishing a dictatorship. After the right environment was created by crushing certain groups, by stamping out certain ideas and making certain internal adjustments, the people, it was claimed, would
automatically fall into a democratic way of living. The State would naturally fade out. But, in spite of this theory, the State today in the Soviet Union seems to be more powerful than it was twenty years ago.

Democracy is a way of life. It is in opposition to autocracy and authoritarianism. It cannot be brought about by autocratic methods; by not allowing people to live it or participate in it. Scientific thinking is a method of thinking that is opposed to authoritarianism. It cannot be developed by autocratic methods of teaching, but only by allowing pupils to apply it and think it.

Morrison never suggests that a pupil be brought face to face with a forked-road situation. He never suggests or plans situations which allow a pupil to hypothesize, test hypotheses by experiment and choose a conclusion on the basis of experimental results. Instead, the teacher or other authority chooses the conclusion, tells the pupil what it is at the beginning of the study and then marshalls certain data, to the exclusion of others, in order to prove it.

Morrison's autocratic scheme of teaching, even though it is in opposition to science, has had a tremendous influence on science teaching in America during the past fifteen years. The Thirty-First Yearbook, Part I, devoted to science teaching and published in 1934 under the auspices of the National Society for the Study of Education, is Morrisonian from beginning to end. Below are a few extracts taken from it:
The new theory requires a curriculum in which...he (pupil) will have opportunity for continuous enlargement of his knowledge of the problems, principles and generalizations that scholarly men find worthy of study.14

The major generalizations and associated scientific attitudes are seen as of such importance that understandings of them are made the objectives of science teaching.15

Subject matter is to be organized into units. By a unit is meant a relatively small mass of learning material, so selected and organized as (1) to clarify a principle and afford abundant drill in its application to such problems as arise in life, (2) to contribute to the attainment of scientific attitudes, and (3) to give abundant practice in the use of the elements and safeguards of scientific thinking.16

Throughout the Thirty-First Yearbook much ado is made about scientific thinking and solving real problems, but little, if anything, is done about allowing pupils to solve interesting forked-road situations which grow out of a pupil's world and which require reflection-level (scientific) thinking for solution. Instead, one-road situations are provided which allow pupils to apply a few mechanical habits. Why certain outcomes are arrived at, rather than others, pupils never discover. Teachers and textbooks are the authorities; pupils are the passive subjects. Again, we repeat that scientific thinking cannot be developed by autocratic and dogmatic methods and by studying one-road situations, whose outcomes are shown at the beginning of the study. The means defeat the ends of democratic education.

15 Ibid., p. 44.
16 Ibid., p. 238.
It is a pity that the leaders in American science education propose methods of teaching which do not allow pupils to reconstruct habits and experiences when, today, our democratic institutions are decaying and falling to the right and left of us, largely because we do not, or cannot, reconstruct these old institutions into modern democratic ones. If the little democracy which we have left survives another twenty years, it will be in spite of the teaching in most schools and not because of it. Before we discard democracy completely, we should give it half a chance to prove its worth by developing pupils in our schools who can carry on a democracy.

The Implications of "To Know Science Is to Know the Method of Science." The implications for the teaching of science-as-method, are that the method and subject matter of science cannot be separated; and that not only the outcomes or end-products (facts and principles) of science should be taught, but also a realization of how particular outcomes are arrived at, and why these outcomes are chosen rather than others.

To avoid separating subject matter and method, and to cause pupils to realize why certain outcomes are arrived at rather than others, pupils must be placed on a frontier of learning and given an opportunity to solve the problems of science by the method of science. Pupils must be given an opportunity to see science in the making.

A scientist or a pupil on a learning frontier is faced with forked-road situations (problems). Most problems in
science and elsewhere do not arise as exercises found in textbooks, listed in categories, each of which can be solved by applying a well-known scientific principle.

The solution of a real problem necessitates scientific thinking. This demands independent learners. Thus, the major implication of science-as-method, like the implications of democracy and relativity psychology, is the development of independent learners.

To find problems for study, we must look for conflicts in a pupil's world. We must look for ideas that conflict with each other, for practices and ideals that conflict, and for ideas that do not jibe with one another. This is the method used by research workers in science the world over.

Why did Newton and Leibnitz, working independently, invent calculus at about the same time? (see p. 7) Why did Young and Fresnel, working independently, discover polarization of light at about the same time? (see p. 180) Why did Einstein attack the problem of relativity and Planck, almost simultaneously, the problem that led to the quantum theory? Why were so many scientists doing research during the "teens" and "twenties" of this century on the electron, and during the "thirties" on cosmic rays? The answer is that these problems were the pertinent or frontier problems at that stage of research; they were problems that grew out of conflicts between old theories and new data; and they were, therefore, the most pressing scientific problems of the time.
An example of such a problem arose in one of the writer's chemistry classes of girls, when we were studying baking powder. The home economics teacher in the school had said that "alum" in baking powder gives baked products a disagreeable taste. To avoid this taste, she recommended the use of Royal or Rumford, the only two brands sold in the locality which did not contain alum.

However, the mothers of several girls in the chemistry class were using alum baking powders, seemingly with success, without experiencing bad taste in the baked product. (Alum baking powders are much cheaper than Rumford or Royal).

But, contrary to this evidence, there were several girls who believed alum baking powder in baked products can be tasted. One said that her father could tell, on first taste, a biscuit or cake made with alum baking powder and would refuse to eat it. She also said that alum baking powder is unhealthful, and for these reasons her mother always used Royal. Others said that since the alum baking powders are so cheap they cannot be as good as the higher priced ones.

In other words, these pupils were saying what many advertisers want every "patriotic" American to believe, and that is: price and quality go hand in hand; the higher the price, the better the quality. But is this true? Here was a problem in economics and advertising, growing out of science. (see p.154)

To add fuel to the smoldering controversy, the teacher suggested to one pupil that she bring to school some newspaper
and magazine advertisements of different brands of baking powder for the period 1910-1925. The conflicting claims that she found were amazing. The following are a few advertisements:

ROYAL BAKING POWDER
Absolutely Pure
Made from Cream of Tartar derived from grapes
ROYAL CONTAINS NO ALUM—LEAVES NO BITTER TASTE

"CREAM OF TARTAR DRUGS ALL FOOD"

"Cream of Tartar, when used in baking, always forms Rochelle Salts..."

' Rochelle Salts are a cathartic, a medicine which so irritates the stomach and intestines that nature sets up an inflammation and a sickness to expel it from the system. This expulsion takes the form of cramps, diarrhea and dysentery. Probably this is the reason many cannot eat hot biscuits without distress.

'Besides this, the salt produces indigestion, dyspepsia and constipation. Whenever there is a tendency to kidney disorders, it aggravates them and in many instances aids in starting the latent disease.

'Calumet Baking Powder leaves nothing injurious in the food.""18

This girl also brought to school some baking powder advertisements which she took from current magazines. All the advertisements were placed on the bulletin board.

In the meantime each girl had consulted her mother on the question. The results were that by the end of two days, all

18 Ibid., pp. 28-29.
were either in a state of doubt, or thought themselves to be decidedly on one side or the other. Nevertheless, they all wanted to know the teacher's opinion as to what is the best baking powder on the market.

Luckily, for the good of the pupils, the teacher was almost as uninformed about baking powders as were the pupils. So we decided to devise ways and means for determining the best baking powder on the market. For a complete discussion of the project (see p.250).

It was by the method described that the problem was raised and made challenging to the pupils. This phase of reflective or scientific study, as has been said, is called the problem raising phase. Bayles says:

No reflective study can get under way until a student has reached the "I don't know" stage, nor will it proceed satisfactorily unless the student is concerned with knowing. Therefore an essential feature of a teacher's stock in trade is the ability to maneuver a class into wanting to obtain an answer to a question which it cannot at first answer.19

But many teachers and school administrators object to the consideration of conflicts or controversial questions in the classroom.

Nevertheless, many of these objectors say that school work should be practical; that is, it should enable pupils better to solve their immediate problems and those which they will meet in adult life. But what is the nature of these

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important problems? Are they controversial, or are they the settled kind whose answers are already known? To answer these questions, let us look about.

As this is being written, more than half the people of the world are engaged either directly or indirectly in war. What kind of problems are they trying to settle? Are not these controversial problems, of concern to pupils? Teachers report that they cannot keep youngsters, even in the lower grades, off the subject of war and its significances. Are not these practical problems? But, is war the best and most practical method that we have of settling them? Seemingly, many statesmen believe so, and the attitudes and actions of many teachers and school administrators seem to imply the same; otherwise they would be interested in making a scientific study of problems of this kind.

Without question, many of the problems over which war is now being waged would have been solved by peaceful means had a vast share of the population of each of the countries involved made a reflective study of the problems in schools and public forums. In the Scandinavian countries, where such studies were made, there has been a desire on the part of the people for peace and they have shown this by reducing their armaments to the minimum, and advocating that international questions be settled by democratic and peaceful means. The fact that these nations are now in the hands of Germany and Russia does not condemn solving problems by scientific democratic and peaceful means. Had the same kind of a study been made in
England and France, as was made in the Scandinavian countries, it is highly probable that a dictator would never have come to power in Germany. Anyhow, today the Scandinavian people are just as well off, if not better, than the people of France.

Not only are there conflicts between groups and among individuals, there also are astounding conflicts in each individual's patterns of thought and action. Seldom are these discussed in school.

The consequence of such education is that we acquire an insensitiveness to the contradictions in beliefs and practices which would otherwise be quite unintelligible. A business man, for example, who has become thoroughly grounded in the notion of business based on competition and as being incompatible with sentiment, joins the Rotary Club, where he absorbs the ideas that business should be conducted in the spirit of service. How these different conceptions harmonize with one another is not immediately apparent... but they seem to dwell in the same bosom without causing any disturbance... The belief in anything is apparently not regarded as a bar to the belief in its opposite. 20

Many other such illustrations can be cited. The following are a few:

The author is acquainted with several women who are well to do financially and who consider themselves devout Christians. These women pay their maids only three dollars per week, and allow them only one half-day of leisure time. Yet these same women are grieving that the Germans are going to make slaves out of the French and other Europeans whom the Germans have recently conquered.

20 Kilpatrick, Bode, Dewey and others, The Educational Frontier, p. 7.
Most business men say that the government, like an individual, should keep its budget balanced. They say also that people should not spend beyond their means. Yet these same business men plan advertising and devise all kinds of "easy" payment plans to encourage people to mortgage property and future income in order to buy unneeded gadgets.

During the past few years, it has been conclusively demonstrated that the perpetuation of our economic system depends on keeping money in circulation. Yet a large majority of the people of our country believe that an individual, as well as the government, should save his money, (the more saved, the better); that taxes should be low; that profits should be high; that both private and public debt should be kept at a minimum; and that inflation should be avoided. But how these people expect to take money out of circulation through savings, profits, and other means, and not put it back through taxes or debt (either private or public), and yet avoid inflation and not destroy the system, is more than a rational mind can understand.

In the writer's home community there are probably twice or three times as many filling stations, grocery stores, restaurants, hot-dog stands, drug stores and other kinds of businesses, as are needed to serve the community efficiently. All of these concerns are open for business six days a week; some are open seven days a week, twenty-four hours of the day. Each day more than fifteen milk trucks, manned by more than
twenty men delivering milk, pass by my house. Bread trucks, laundry wagons, grocery wagons and produce trucks stream by daily, each duplicating the services of a dozen others. As a consequence, hundreds of people do long hours of needless and unnecessary work; the cost of distribution of goods is increased; and wealth is wasted.

The only business concerns that appear to be efficiently operated and appear to render the maximum service at the lowest cost per worker are: the city water plant which is publicly owned and operated, the United States post office, the public schools, the police department, the city library, the telephone company and the electric light company.

Yet, in face of these facts, a large majority of the people in the community, of about 12,000 people including about 500 college professors and more than 100 other public school teachers, believe that public enterprise is far more wasteful, more inefficient and more costly than private enterprise.

A twelve year-old child could make the observations above and arrive at a conclusion in keeping with the data. However, most adults do not. Their thinking is beclouded by prejudices, sentiment, propaganda and emotions to the point that they can actually believe what consistent logic and observation both deny.

Without question more than forty per cent of the people in this community have a college education, and at least sixty
per cent have a high school education. Even so, in most of
their bosoms reside glaring conflicts which never seem to
collide. Ideals and practices conflict at every turn, yet
the individual is not cognizant of the condition.

Not only do conflicts exist in the thought and action
of our people, but Western culture itself is one big conflict.
There is little or no relation between ideals and practices,
or between theory and action. Western civilization is like a
big monster with a thousand heads, each trying to go in a dif-
ferent direction. And, as this is being written, it seems to
be crumbling and falling apart.

Even so, many teachers object to the study of the import-
ant conflicts of our culture. Recently a high school teacher
of history said to the writer:

We cannot study conflicts; the pupils are too young. They are not
interested. The only thing I can do is to assign them lessons in their
books and make them learn what is assigned. Of course, if I had gradu-
ate students, I might study conflicts.

Bayles' answer to the argument that children cannot be
interested in conflicts is:

Inadequacies, confusions and con-
licts when discovered and identified,
constitute problems which are of real
concern to anyone, because perhaps no
normal person can become convinced
that his outlook upon life is inad-
quate, confused or internally conflict-
ing and not be moved to do something
about it.21

21 Bayles, E. E., Associate Professor of Education,
University of Kansas.
However, it should be remembered that the conflicts must grow out of the pupil's world and not out of the adult's world.

Certain teachers object to the method of choosing subject matter proposed (choosing for study the most confusing problems in the pupils' world) because all pupils may not be interested in the same problem; therefore a minority of the class may be forced to solve problems which they do not wish to solve. These teachers say that in order to be democratic we must let each pupil do what he pleases. For example, in a chemistry class, if John wants to make candy while the other pupils study baking powder; John should be allowed to do so.

As Dewey says:

> There is a present tendency in so-called advanced schools of educational thought (by no means confined to art classes like those of Cizek) to say, in effect, let us surround pupils with certain materials, tools, appliances, etc., and then let pupils respond to these things according to their own desires. Above all, let us not suggest any end or plan to the student; let us not suggest to them what they shall do, for that is an unwarranted trespass upon their sacred intellectual individuality since the essence of such individuality is to set up ends and aims.\(^\text{22}\)

The trouble with people who hold beliefs of this kind is that they do not recognize the difference between democracy and anarchy. They do not realize that in a democratic society the individual owes certain responsibility to the group. The ideal democratic society, which we have proposed is one which

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provides equal opportunity for participation in a growing area of interests mutually shared by the group. Bruce says:

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\text{Education for democracy does not mean that a fifth-grader is free to play and dawdle...} \text{each school youngster must learn to recognize definitely and shoulder willingly his share of the work.}\)

If a boy plays baseball, his team mates expect him to play one of the nine positions and play it to the best of his ability. They do not expect him to loaf while the others retire the opponents. But, this does not mean that the boy is regimented or that he is fitted into a predetermined mold. Instead, it means that he has an opportunity to participate; but in accepting the opportunity, he also assumes the responsibility of cooperating with the group to attain the goal of the group.

It is the goal of the group, and the individual ability of a boy, that should dictate whether he pitches, catches or plays in the field. The slow, sturdy lad should not try to play in the field or at shortstop because he is too slow. He should catch, play first base or pitch.

If a manager is elected to select players and perform certain prescribed duties for the group, each boy should have a vote in determining who it will be. Even though the elected manager is not the choice of a particular boy, that boy is honor bound to play to the best of his ability as the manager directs. However, he has the privilege at all times of in-

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fluencing others to elect a new manager at the next election. Such is the democratic way.

Likewise, a pupil in a science class, conducted in keeping with democracy, will not always be at liberty to do as he pleases any more than is a child who plays baseball. If a boy decides to take chemistry, he should expect to study chemistry; not basket ball. If a majority of the class decides to do something that he does not wish to do, it is his responsibility to go along with the others and do his part. However, all should have an equal opportunity to decide what problem shall be studied and each should have an equal opportunity of participating in the solution of the problem decided upon. The nature of the problem and the pupil's ability should determine the part that each does. Most real problems will supply wide choices for individual participation.

In solving the problem, "What is the best baking powder?" (see p. 230) every pupil did not do the same thing. Much opportunity was allowed for individual differences. Those most interested in cooking volunteered to bake biscuits for the taste test; those who wished to learn how to sample public opinion, how to make a questionnaire, and how to interview people, volunteered for these activities. But the findings of each group were reported to the class so that all shared in the outcome. Bruce says:

The adoption of a unit method procedure is not justifiable unless it results in developing the ability of pupils and teacher to work together constructively. Opportunities must be given for
each member of the group to participate creatively in the planning of the unit... Since each individual is given opportunity to participate creatively in planning and executing group activities, the youth's school experience actually prepares him for responsible citizenship in a democratic community. He learns to participate actively in the process of continually widening the area of his own purposes and, thereby, of the common purposes of the group members.24

In conducting a class in this way, it does not mean that the teacher dictates to the pupils nor that the pupils dictate to the teacher. Dewey sizes up the pupil-teacher relationship in making choices of subject matter and planning the unit in the following paragraphs:

Moreover, when the child proposes or suggests what to do, some consequence to be attained; whence is the suggestion supposed to spring from? There is no spontaneous germination in the mental life. If he does not get the suggestion from the teacher, he gets it from somebody or something in the home, or the street, or from what some more vigorous pupil is doing. Hence the chances are great of its being a passing and superficial suggestion, without much depth and range—in other words, not specially conducive to the developing of freedom. If the teacher is really a teacher, and not just a master or "authority," he should know enough about the pupils, their needs, experiences, degrees of skill and knowledge, etc., to be able (not to dictate aims and plans) to share in a discussion, a discussion regarding what is to be done and be as free to make suggestions as anyone else. (The implication that the teacher is the one and

24 Bruce, William, Principles of Democratic Education, p. 94.
only person who has no "individuality" or "freedom" to "express" would be funny if it were not often so said in its outworkings.) And his contribution, given the conditions stated, will presumably do more to getting something started which will really secure and increase the development of strictly individual capacities than will suggestions springing from uncontrolled haphazard sources.

The point is also worth dwelling upon, that the method of leaving the response entirely to pupils, the teacher supplying, in the language of the day, only the "stimuli," misconceives the nature of thinking. Any so-called "end" or "aim" or "project" which the average immature person can suggest in advance is likely to be highly vague and unformed, a mere outline sketch, not a suggestion of a definite result or consequence, but rather a gesture which roughly indicates a field within which activities might be carried on. It hardly represents thought at all; it is a suggestion. The real intellectual shaping of the "end" or purpose comes during and because of the operations subsequently performed. This is as true of the suggestion which proceeds from the teacher as of those which "spontaneously" spring from the pupils, so that the former does not restrict thought. The advantage on the side of the teacher—if he or she has any business to be in that position—is the greater probability that it will be a suggestion which will permit and require thought in the subsequent activity which builds up a clear and organized conception of an end.25

In other words, Dewey is saying that choice of subject matter is made by pupils and teacher together, and that problems grow out of what has proceeded. This latter point will be

extremely important when we consider the organization of subject matter.

After a problem has been raised, the next step is to propose alternative solutions (hypotheses or answers); to consider the implications of each in terms of the situation; and, if necessary, test each hypothesis by experiment. As an example, let us consider the question, "What is light?"

One answer or hypothesis that might be proposed, and was actually proposed by Euclid and Aristotle, is that light is tentacles or rays that are emitted by the eyes and the eyes only. If this hypothesis is correct, one should be able to see on entering a completely darkened room. And then, too, a blind man should not be able to take a picture with a camera in the absence of anyone who can see. From actual experience we know that the implications of Euclid's hypothesis in these two instances do not square with fact. In other words, this hypothesis cannot be used to predict data reliably. For this reason, we rule it out.

Another hypothesis that might be proposed, and was proposed by Newton, is that light is matter (corpuscles) emitted by an incandescent substance. If this hypothesis is correct, light should have mass and thus have weight. But does it? And, too, a substance that emits light, such as a red hot coal, should lose weight as light is emitted. But does it?

Also, according to Newton's corpuscular theory (see p. 172), light should travel faster through the denser of two mediums. But common sense tells us that it should travel more slowly.
through the denser, just as a bullet shot from a gun travels more slowly in water than in air.

To test the implications of Euclid's theory, we referred to experience. To test the implications of Newton's theory, we must resort to laboratory experiments, or, if this is not feasible, to authoritative data collected by other experimenters. In this way, experiments are made real and purposeful. They are used to test hypotheses.

If experiments do not verify an hypothesis, it is ruled out; if an hypothesis is verified, it is strengthened. In this way, all hypotheses can be eliminated except one; the one which best explains all available data and is most reliable in predicting new data.

For a complete study of the problem "What is light?" as we believe it should be presented in a textbook, see Chapter VI. Note there how new problems grow out of old ones, and how knowledge is enhanced and new insights are developed. Also note how one conflict after another is resolved, and how the new is integrated with the old or the old with the new. Note also that as one problem grows out of another, a continuum of thought unfolds. Bagley's phrase, "trunklines of human thought," is well exemplified by subject matter organized in this manner; far better perhaps than by any other form of organization yet employed in school.

Even though an understanding of science demands knowledge of the inter-relatedness of science subject matter, the members
of at least one so-called school of "Progressive" education will take exception to the organization of subject matter in Chapter VI on the grounds that science is compartmentalized, and that for this reason, a pupil will never integrate what he learns in science with what he learns in, say, history or government.

Such "Progressive" educators claim that the only way to get integration is to make one subject, such as social science, the core from which all other topics obtain place and meaning. To illustrate, suppose transportation is the topic to be studied. Since transportation involves science, mathematics, history, and what not, then when pupils need to know about the science of transportation, they will be sent to the science class. Likewise, when pupils need to know about the history of transportation, they will be sent to the history class. Thus the study of mathematics, literature, and other subjects is made purposeful and at the same time presumably all are integrated. Why a study of transportation is purposeful is never made clear. "The effect of this," says Kilpatrick, "will be to find arithmetic in many little pieces scattered along the path of life. These we shall teach as we meet them."26

The result, presumably, will be that all subject matter will be integrated by a pupil and conflicting ideas will not

26 Kilpatrick, Foundations of Method, p. 357.
reside in the bosom of the future business man and others. All ideas will be in harmony with each other.

In analyzing this scheme, let us look closely at the kind of mental procedure which has effected integration in science itself. At the opening of the twentieth century, as we know, Newtonian physicists were of the opinion that they had discovered virtually all of the universal physical laws and that their "picture" of the physical universe was about perfect. Up to that time, they had been able to fit most new knowledge into the body of related knowledge which they had already discovered, classified and systematized. Thus, the new and the old were integrated by fitting the new with the old; not the old with the new. But several new discoveries, made about 1900, would not fit into the old picture. When the attempt was made, the result appeared much like a daub of red barn paint on a portrait by Rembrandt.

However, most of the scientists of that day were such firm believers in the philosophy of classical physics that they were unable to even consider the new discoveries; they utterly ignored them. "Surely something is wrong," they said, "with the observations and the experiments." Because they assumed that the physical knowledge which had already been discovered was final and absolute, it was impossible for them to pin any faith on new data that disagreed with the old.

Nevertheless, there were a few scientists who were able to face the facts even though the facts did not agree with
the cherished prejudices of most physicists. One of these was Einstein, a true scientist, whose thinking was not restricted by convention, prejudice, antecedent conceptions and prior philosophy. He realized that it was impossible to explain honestly the new data in terms of Newtonian philosophy; that is, by imposing Newtonian philosophy upon it. Intellectually, he was honest and he faced the situation squarely. He was able to do this only because he had trained and disciplined himself to think reflectively. He was an independent learner.

In integrating the old and the new, Einstein literally tore up the old picture and painted a new one. Instead of integrating the new with the old, he integrated the old with the new. Einstein staged a revolution in physical thought. In so doing, he developed a new theory, based on assumptions that are diametrically opposed to the assumptions of the Newtonian theory.

But the average individual who has been through our public school system shuns putting two sets of conflicting data alongside of each other and harmonizing the two by reflective study. If he is faced with a conflict, as a rule he either ignores it or makes decisions on the basis of his prejudices. He cannot consider even the simplest facts and observe the simplest situations, which disagree with his previously established prejudices and cherished conclusions and form an opinion in keeping with the facts.

Hence, in view of what has just been pointed out, we doubt very much whether scrambling a little science, a little history,
a little mathematics, a little literature and calling it a
study of transportation, will cause a pupil to integrate his
thinking more than he would in the traditional compartmental-
ized-subject-matter school. In fact, such a scrambled curri-
culum is likely to result in disintegration.

As has been pointed out, science like mathematics is a
highly related body of subject matter. In science, there is
continuity of thought and dependency for meaning of one idea
upon another. One idea leads to the next; one idea is related
to the next; and unless this relatedness is sensed by the
learner, science is not understood. Science in itself is an
integrated body of subject matter; it is a whole in itself,
and can be understood only when studied as a whole.

Even Thorndike admits that the more closely knit and
logical a set of ideas are for a learner, the more easily they
are understood and learned. But, if science is studied in
unrelated bits, as is done under a core curriculum, how can a
pupil's outlook on the world of science become integrated?
Moreover, unless science itself is understood and integrated
by a pupil, is a pupil likely to integrate science with other
subject matter?

When one endeavors to fit isolated bits of knowledge to-
gether, there is no background of knowledge nor any picture
to fit the new into. There is no way of checking the new and
the old against each other; there is no way of finding con-
licts which make reflective study possible; there is, in brief,
no possible way through which integration can take place. Unless ideas are related and made into a whole, they have little or no meaning.

The results of such a situation are that reflective study is impossible; that there is no necessity of knowing the basic organization of knowledge; that pupils can be easily led to believe almost anything; and that education as reconstruction of experience is impossible.

Kilpatrick—a believer in cutting across subject matter lines, and in the project method whereby each pupil is surrounded by tools and other materials and allowed to work at whatever project he pleases—believes that the way to offset the inadequate knowledge of fundamental, organized subject matter is to take time out, now and then, to drill pupils in fundamentals.

I think there are certain things so useful for future progress in school and life, both immediate and more remote, that we should use compulsion if need be to get them, so important that if they are not got otherwise, there would eventually come a time when we should, if need be, drop practically everything else and compel the learning of them. Only I cannot give you a complete list...My general list for all would certainly be much smaller than you are accustomed to think.27

Rode says:

On casual inspection, at any rate, this looks like an oscillation between two extremes. On the one hand the

teacher all but fades out of the picture; on the other hand, the teacher functions like a drill sergeant in charge of the awkward squad. 28

Kilpatrick makes it very easy for anyone to agree with him. For some teachers the list may be long, and for others it may be short. If the list is long, then teaching is right back in the old groove from which we have been trying to escape. As was shown in Chapter IV, Kilpatrick separates method and subject matter, a separation which results in the old conflict between interest and discipline. This in turn brings in the conflict between autocracy and anarchy.

Lack of integration in the past has not been because of any inherent characteristic of subject matter. It has been due largely to the method of teaching and of selecting subject matter.

Integration can be attained only by bringing a pupil face to face with challenging conflicts which he can resolve through reflective study. If we want to develop pupils who will effectively iron out the conflicts in their thinking, we must develop independent learners; that is, pupils who are trained and disposed to search out conflicts in their own thinking and in their culture, and who will resolve them by scientific study. Unless pupils do become independent learners they will shy away from conflicts and will make no effort to harmonize them.

28 Bode, Modern Educational Theories, pp. 162-163.
In a study of several different "scrambled" or core curricula—for example, those proposed in Arkansas, Kansas and Virginia—problems that involve conflicts and require reflective study for solution are not to be found. But some are going to say, "How can integration of subjects, such as science and economics, be gained if the curriculum is not scrambled?" Let us see.

In the previously described study of baking powder, the following challenging questions arose: Is price a criterion of quality? How truthful is advertising? Do advertisements furnish data that can be depended upon in making wise choices in buying? Is the advertising of staple goods, such as salt, sugar, baking powder and soap, an economic waste? And if it is, why is it done? Do manufacturers of consumer goods, as a rule, furnish reliable information which can be used by the consumer for making wise choices in buying? If not, why not?

Elsewhere, we have seen that the philosophy of relativity science does not agree with a certain political philosophy which is in effect that our economic problems will solve themselves if we trust God and the Law of Supply and Demand. Also science teachers and science books advocate that each child drink a quart of milk a day, but seldom say anything about how the eight Jones children, whose father makes only fifteen dollars a week, can each get this much milk, and at the same time be decently housed, clothed and fed anything besides milk. Nor is anything said about whether children who come to school
under-nourished and ill clothed, have the same opportunity to
develop their personalities and become self-assured and confi-
dent as those who are well nourished and well clothed. How
does such a situation square with our definition of democracy?

These questions are conflicts, involving economics, which
grow out of science. These conflicts are caused by science
impinging upon our economic and social structure. They are
the social implications of science for the teaching of econ-
omics. Only by resolving conflicts such as these will science
and economics become integrated. However, the proper place
for a detailed study of such questions is in economics, not
in science; for in economics, pupils should have proper back-
ground of related facts and principles to make reflective
study possible. Without proper background, reflective study
is impossible and teaching can be no more than indoctrination.
In studying the proposals made by the leading advocates of
core curricula, the writer has often wondered whether cutting
across subject matter lines is not a deliberate scheme for
effecting indoctrination.

No matter what type of curricular organization is used,
unless teachers are aware of conflicts in our culture, are
looking for them, are disposed to bring them into the open,
and are disposed to attempt their resolution by cooperative,
reflective study, little or no integration will result.
Neither a scrambled curriculum, a compartmentalized curriculum
nor any other kind of curriculum will bring about integration
unless proper methods of teaching are used and proper subject
matter is chosen.
We have already discussed the part played by pupils and teacher in choice of subject matter and getting a study under way. The next question which naturally arises is what part should pupils and teacher play in the solution of a problem; that is, what part should pupils and teacher play in making a choice from the several alternative hypotheses proposed? Before answering this question, let us find how a group of scientists working together arrive at a conclusion.

Among scientists, the word of no particular individual is sacred. The suggestion of the lowliest laboratory assistant is taken for what it is worth, just as if it came from one in highest authority. The mode of organization of congeries of scientific men is never autocratic...Each member of such a group must be intellectually free to follow the logic of his own thought processes; but he is also intellectually bound to follow such a logic. In other words, among scientists there is equality of freedom, and at the same time equality of responsibility.

In the classroom this means first of all, that if scientific mindedness is desired, the organization must be democratic. Neither can we permit the teacher to say to the student, in effect, "You must believe as I believe," nor can we permit him to say, "You may believe as you please." While it is not educative for the teacher to dictate beliefs to the student (even if he could), neither is it educative for the teacher to adopt a "hands off" policy regarding student beliefs.29

But if a pupil is not to be forced to agree with a teacher or other authority, or may not believe as he pleases, then what

29 Bayles, E. E. Obligations of Teaching in a Democracy, Journal of Educational Administration and Supervision; April, 1939.
is he to believe? What are the criteria that he may use for knowing what to believe and what not to believe?

The criteria that a scientist uses are: (1) Which theory or hypothesis most easily, most naturally and most adequately explains or harmonized all of the data? (2) Which theory is the best for predicting new knowledge?

If these criteria are adopted for choosing alternative hypotheses, then it becomes the duty of both teacher and pupil to see that all pertinent data are presented. This does not mean that the teacher should dogmatically introduce a problem, propose a certain solution to the exclusion of other possible solutions, marshal data which agree with the preconceived solution and exclude data which do not agree.

After all available, pertinent data and various hypotheses are presented, the duty of the teacher is to determine how each pupil arrives at his conclusion; whether he considers all the facts and whether the conclusion appears to be in keeping with all the facts. If the conclusion is not a seemingly justifiable one, the pupil should be challenged either by other pupils or by the teacher and asked to explain why his conclusion is in disagreement with the facts or why it does not explain all of them. Guidance on the part of the teacher is to get the pupil to agree with himself, and ever to broaden and harmonize his outlook on life.

But, what if the teacher and a pupil have access to the same data, but cannot agree among themselves on the same conclusion? In such a case, as in any other case wherein human
beings respect each other, teacher and pupil should respect each other's opinions and rights and there should be no hard feelings on the part of either. But both teacher and pupils are honor bound in reaching a conclusion to take into consideration all the data. This is the scientific and democratic way; it is not the autocratic way of the teacher trying to force a belief upon a pupil, nor the laissez-faire way of allowing each pupil to believe as he pleases without first being thoroughly challenged in case he has disregarded a part of the data, or his conclusion is not in keeping with the data.

Of all teachers, perhaps the science teacher has the greatest opportunity for teaching intellectual honesty; a trait sorely needed among all people the world over. And, in the writer's opinion, the method of teaching herein described is the only method by which such a trait can be taught.

As science textbooks and laboratory manuals are now written, a pupil, before he begins an experiment or exercise, either knows the answer or can easily find it in his book. And he knows, too, that his grade depends upon arriving at "the" (authoritative) answer. The result is that the pupil works for the answer and if he does not get it, he "doctors" his data. Opportunities to weigh data, to hypothesize, to choose and judge the correct answer from various hypotheses, are non-existent, except by chance.

Bookkeepers who balance their books by "doctoring" figures, if caught, are sent to prison. But, in school such methods are
considered clever by the "run" of pupils and are overlooked by teachers. Intellectual honesty is discouraged at every turn. Yet teachers wonder why there is so much dishonesty in the world outside of school and so much cribbing in school.

Only when textbooks and laboratory manuals are written and designed so that pupils are confronted with challenging problems and experiments--answers to which are unknown and can be obtained only by considering alternative hypotheses--and only when teachers emphasize the method of arriving at answers, rather than emphasizing exclusively the answers themselves, shall we develop intellectual honesty and scientific mindedness on the part of pupils.

Of course, objections will be raised to this method of reaching conclusions on the grounds that in many instances all of the data cannot be presented. On the surface, this objection seems sound; but if one stops to consider one realizes that there are very few, if any, questions about which we have all the data. Nevertheless, we make conclusions and act in accordance with them. Newton acted, believing he had all the data; Einstein acted, knowing he did not have all the data.

The question of whether one can be scientific, yet act on the basis of available, but incomplete data, or must defer action until all of the data are found, is a critical question which faces Western civilization. Although the issue has never been presented squarely to the American people, certain political groups, in effect, say, "We cannot do anything to solve
our economic and social problems because we do not know enough; we do not have enough data. Let things alone, and God and the Law of Supply and Demand will take care of us." This idea, along with the one held by many that what is, is good, prevents any really experimental solution of our economic and social problems.

Time and again the writer has heard university professors—physicists as well as professional educators, all believers in scientific materialism and that facts speak for themselves—say, "We cannot act until we have all the facts." And these same educators are always barking that education will become a science when we get all of the facts. Luckily for scientific advancement, many such believers have unknowingly acted out of accord with their stated philosophy. We wonder what would be the status of aviation today had aviators and scientists waited for the perfect airplane before taking the risks of flying.

As Dewey has pointed out time and again in his writings, the first step in science is to change something and see whether what is anticipated happens. In other words, the only way to learn, other than by mere observation of what naturally exists and occurs, or by being told, is to hypothesize on the basis of the available data and test the hypotheses. This is what true scientists do.

This is what Mr. Jones did when he was trying to start his automobile (see p. 72). He hypothesized on the basis of
the data at hand and then tested these hypotheses. In acting (experimenting), he obtained more data and these caused him to eliminate certain hypotheses and to pin more faith on others. Thus, theory and practice (hypothesis and experiment) worked hand in hand. Facts were a basis for hypotheses, and hypotheses served as bases for experiment (action). By realizing the consequences of the acts, new facts were discovered and new insights were developed which better enabled Mr. Jones to direct his subsequent acts. This method of solving problems is the truly experimental method.

But many readers are going to say, "What has this question to do with teaching science to a five, eight, twelve, or thirty-year-old?" Whether science is taught either in keeping with the absolutism of scientific materialism, or with the relativity of pragmatism, may determine a pupil's whole outlook on politics, economics, religion and influence all phases of his cultural and emotional life. And it is upon the people's outlook that the fate of Western civilization largely depends.

In Western civilization, within almost every field of human endeavor, there is active conflict between absolutism and relativism. Among nations, as this is being written, there is war between dictatorships (fascist and communist) and democracies; within the churches, there is a fight between liberals and fundamentalists; among scientists, there is a clash between relativists and classicists; among philosophers, there
is heated argument between pragmatists and absolutists (both idealists and materialists); and among professional educators and psychologists, there is a quarrel between the relativists and behaviorists. Bode says, "The real conflict in Western civilization is between authoritarianism and true science and not between fascism and communism." Bode made this statement in his summer school commencement address at the University of Missouri in 1938, at which time the communists and fascists seemed to be in armed conflict in Spain. Since that time, the minor differences between these two factions seem to have become unimportant.

Although the issues are not well defined in many instances, there is a distinct tendency among conflicting sides in all fields of human endeavor to take a position in keeping either with absolutism, autocracy and authoritarianism on the one hand, or with relativity science, democracy and true Christianity on the other. On which philosophy shall Western civilization of tomorrow be based?

No doubt, teachers of science will influence the outcome; but, as long as science teaching remains a process of indoctrination and science subject matter is taught as authoritarian and absolute knowledge, science teaching will have little influence on the promotion of the scientific attitude, of democracy, or of true Christianity because none of these are fostered by autocratic methods. Autocratic methods defeat the democratic ends of science, democracy and Christianity.
CHAPTER VI

ILLUSTRATIVE MATERIAL

Two illustrations, each of which differ widely, have been chosen to exemplify the relativity theory as it applies to teaching science. Only one problem is considered in this Chapter. The other is presented in the appendix.

The first, "What Is Light?", is a problem in physics, written for a textbook to be used by high school juniors and seniors. It is assumed that pupils have had at least one semester of physics in which they have made a thorough study of matter, energy, and wave phenomena. This, and the fact that this chapter is illustrative material, should be kept in mind.

The basic subject matter presented is practically the same as that found in a number of high school physics textbooks; in fact, no material is considered that is not included in at least one book now in use.

The major difference between this study and others is the approach. We have tried to make "What Is Light?" a real problem. In trying to solve the problem, we have presented various possible hypotheses; then we have considered the implications of each. That is, we have tried to predict what has to be true if the hypothesis is true.

The predictions we subject to experimental test. In this way, experiments are connected with purpose. If the predictions do not square with fact and with experimental findings, we rule out the hypothesis as a likely solution to the problem. In this way, each hypothesis is tested.
Another test of a hypothesis is whether it naturally and easily explains all pertinent data. If a hypothesis explains the data, it is strengthened; if it does not, it is ruled out.

Throughout, there is continual reconstruction of knowledge. The new and the old are reconstructed and harmonized in the light of each other, and the reconstructed knowledge is used to predict new knowledge. It is in trying to integrate old and new knowledge that mental conflicts (new problems) arise. Thus, one problem psychologically grows out of another. In this way, subject matter is arranged as a growing mind would learn it; it is arranged psychologically. And the reconstruction of the old and new makes for logical as well as psychological organization.

Another psychological feature is the problematical situations which are developed. There are always at least two possible outcomes. Which one will triumph the pupil does not know. One theory is played against another, as is done in a good detective story and as actually did occur in the original, historical development of the ideas proposed. By making such a study the pupil witnesses science in the making.

The approach is historical but the historical facts are not ends in themselves, they are a means to an end. The history of science is as thrilling as a good detective story. Hundreds of unknown men have died for science. Some have suffered through poverty, sickness, persecution, war and famine, but still have carried on. Some have sought personal glory and monetary gain; some have sought to improve the lot
of suffering humanity; some have sought thrill and romance; and some have had only an insatiable curiosity about the universe. Some have been petty, jealous, conceited, and narrow-minded, working in secret, giving little or none of their work to the outside world. Others have been open-minded, generous, kind-hearted, and self-sacrificing, giving all to the world in order that others might carry on where they left off. Scientists have arisen from the ranks of the poor as well as from the ranks of the rich. Representatives of every nation, creed, and color can be found among the famous.

Through a historical approach, all this can be brought to pupils. Here, the relativists say, is a great opportunity for the development of attitudes and habits. What we try to do is summarized by Bode in the following excerpt taken from a personal letter, written in February, 1940.

Let us say that democracy means, roughly, the development of the individual as a test of the quality of social relationships. What does the teaching of science have to do with this? Well, in the first place, science introduced a distinctive way of dealing with problems. This can be brought out clearly only by contrast with pre-scientific thinking. It introduced a different perspective on the universe--no cleavage between the natural and the supernatural. It affords the suggestion that the concepts of science are essentially "tools." Tools for what? For the control of experience: i.e., for the furtherance of human purposes. This puts the individual squarely in the center of the picture. It leads on to the relativity of truth, of which science offers numerous examples. The import of all this is a break with traditional, pre-scientific beliefs and standards. The emphasis on the individual is essentially democratic. The insight that science
can give is necessary for an understanding of the present. The central issue is this choice between the implications of science and traditionalism. Put this across by proper and constant use of contrasts and you'll have adolescents rising out of their seats. They want to know what the shooting is all about. Show them the issue—don't try to decide it for them. For this purpose science is indispensable, but science teaching almost invariably goes off on all kinds of tangents instead of emphasizing the broad human meaning of science which every educated person should know: The conception of the universe (as against supernaturalism), the meaning of scientific concepts and of truth, and the bearing of all this on making man the central figure. This would call for extensive and constant use of contrast, use of the history of science.
WHAT IS LIGHT?

Probably, from the time that the first person was able to see and think, man has asked the question, "What is light?" If prehistoric man were like historic man, he was not long in formulating some kind of an explanation.

During historical times, several theories of light have been proposed. To us certain of these seem preposterous, even absurd. But they were not absurd to people at the time they were proposed. Do you believe that many of our ideas and things we do will seem absurd to people of future generations? Why?

Theories of light, like many theories in science and in other fields, have come and gone. Some have led into blind alleys and held back progress; others have pointed the way to future discovery.

Euclid's Theory of Light. The theory of light that held sway the longest was proposed about 300 B. C. by Euclid, a Greek philosopher and mathematician. According to Euclid, light is ocular beams which are emitted by the eyes and the eyes only. A blind man's eyes emit no light, therefore he cannot see.

According to this theory, should you see at night as well as in the daytime? Should you see on entering a completely darkened room? Could a blind man take a picture with a camera in the absence of a seeing person? Do your answers square with fact? Use this theory to make other predictions. Do they square with fact? Do you accept or reject this theory? Explain.
As has already been pointed out, the Greek philosophers and their followers, like many people today, never subjected their theories to observation and experiment. This is one reason why Euclid's theory held sway so long. Sir Isaac Newton (1642-1727), was the first to advance a consistent theory of light based on observation and experiment.

What Was Newton's Theory of Light? Newton believed that light is minute corpuscles (particles of matter) emitted by a luminous body such as the sun, a burning candle, or a red hot coal. The particles travel in straight lines. And the more particles or corpuscles emitted per unit of time, the brighter the source. Corpuscles striking the eyes cause the sensation of sight. This theory is known as the corpuscular theory.

According to Newton's theory, should one see on entering a completely darkened room? Could a blind man take a picture with a camera in the absence of a normal seeing-person? Should light have weight? Plan and perform an experiment that will check your answer for the last question. Account for your results as Newton might have explained them.

"But why," you ask, "can we see non-luminous objects such as trees, chairs, and tables?" Newton believed that it is because light is reflected by such objects. Reflected light causes the sensation of sight just the same as does direct light.

Does Light Travel In Straight Lines? Newton said that light travels in straight lines. If this is true, should you see around a corner? Can you? To test further whether
light travels in straight lines, punch a hole, about an eighth of an inch in diameter in each of three sheets of paper and place each sheet some distance apart so that you can see through one hole, on through the next one and so on. Are the holes in a straight line?

Fig. 3. Does light travel in straight lines?

In the diagram above, place the edge of your ruler on the source of light S, and on point P of the object so that the edge extends to the shadow. Does the edge of the ruler lie on the edge of the shadow?

Keeping the edge on S, move the ruler so that the edge also lies on D; on R; on M. In each case does the edge lie on the edge of the shadow? What is your conclusion from these observations?

Does the edge of the shadow appear sharp and clean cut? Would it, if light bends around the object; that is, if it does not travel in straight lines?

Shadows and Eclipses. The source used above is a point source. Arrange two lighted candles and a cylindrical object on a table as shown in the diagram below and then darken the room.
Fig. 4. What Kind of a Shadow Is Formed?
Assuming that light travels in straight lines, explain why there are two distinct parts of the shadow. What is the name of each part?

Arrange, as shown in Fig. 5, a 100-watt, frosted electric light bulb, a spherical opaque object, and a screen. Then darken the room. Explain why the shadow cast is not sharp and clean cut around the edges. What is an eclipse? Partial eclipse? Total eclipse? Plan a demonstration that will illustrate both kinds.

Fig. 5. What is the Nature of the Shadow?

Does Light Always Travel In Straight Lines? Darken the room and then allow a narrow beam of light to strike the surface of a boiled-starch-water solution which is in a glass container. Make a drawing of the beam of light as shown in Fig. 6. The normal is a line drawn perpendicular to the surface at the point where the light strikes it.
Fig. 6. Is the beam bent?

If the beam is not bent at the surface, it should travel along the dotted line BC. Does it? If it does not, show in your drawing what happens. Is the beam bent toward the normal or away from it? The bending of light as it passes from one medium to another is called refraction.

If a beam of light were passed from water into air, do you predict that it would be bent at the surface toward the normal? Away from the normal? Not be bent at all? Plan and perform an experiment to test your prediction. Also try passing light through a vacuum, through glass, and through other substances furnished by your teacher.

How Did Newton Explain Refraction? To explain refraction, Newton said that the corpuscles of light approaching water are attracted by it in a direction perpendicular to the surface of the water in accordance with the law of universal gravitation. Since the force of attraction is slight until the corpuscles are right at the surface, the beam is not bent until it reaches the surface.

Because of their inertia, the corpuscles, when they strike the water, tend to continue in a straight-line course. However, the attraction of the liquid pulls them away from
this course; and as a result, the beam is bent toward the normal.

Since the denser medium (water) has a greater attraction for light particles than the less dense medium (air), Newton predicted that the light particles would speed up as they enter the denser medium and would therefore travel faster in it. Can you think of a reason why they might do the opposite, that is, slow up?

Wave Theory of Light. About the same time that Newton proposed his theory, Huyghens (hi-genz), a Dutch astronomer and physicist, advanced the wave theory of light. He believed that a luminous source emits light which is a wave motion that travels in all directions from the source and is reflected by non-luminous objects as Newton believed corpuscular light is reflected. His explanation of the cause of sight sensation was the same as Newton's.

Newton Objects to Huyghens Wave Theory. Newton would not accept the wave theory. He argued that, "Sound, which is a wave motion, will travel through a crooked hollow pipe or will bend around a hill or other obstruction and be heard."

"Therefore," he said "if light is a wave motion, it too should travel through a crooked pipe or around an object. And, therefore, an eye should see around a corner."

In reply Huyghens said, "That is not a convincing argument. Take short water waves on a river striking the side of a ship; the waves originating on one side will not be seen on the other. If the waves are small enough and the ship large enough, a very distinct shadow appears. However, if the waves
are large and the obstacle is small, the waves will bend
around the obstacle and no shadow will appear." Huyghens
predicted that if one could procure a sufficiently small
obstruction, it would cast no shadow.

There were other reasons why Newton would not accept
the wave theory. "Every wave" he said, "must have something
in which to travel. Light travels through a vacuum, whereas
sound does not. Corpuscles need nothing to travel in, but
waves do. What do light waves travel in as they pass through
a vacuum such as the vast inter-stellar space between the
sun and the earth?"

Newton and his followers could no more think of a light
wave without something for it to travel in than they could
think of an ocean wave without an ocean.

**What Do Light Waves Travel In?** To answer this question,
Huyghens did what psuedo-scientists and good scientists had
done before him and have done since in like situations. He
assumed the existence of a substance. He called it ether.

What are the implications of this assumption? Does ether
exist in the vast inter-stellar space between the sun and
earth? Explain. Does it exist in transparent liquids and
solids? Is there any reason why ether might not exist in
opaque liquids and solids? Huyghens believed that ether is
a fluid-like substance, perhaps more like jelly than air,
which fills all space and permeates all matter.

Again Newton objected. "What is this ether?" he asked.
"I cannot see it, feel it, taste it, smell or feel it," he
said. "Does it stand still or does it 'blow' like the wind?
Is it frictionless? If it is not," he asked, "then what prevents the earth and other planets, which are rotating and moving about in it, from running down like a spinning top?"

Newton viciously assailed the wave theory, and as a result, few scientists accepted it. To doubt Newton was to doubt "the" scientific authority of the world. It was the "Age of Newton." However, the test of a theory is not who proposes it but whether it can be used to predict new knowledge and explain facts pertaining to it.

How did Huyghens Explain Refraction? The diagram at the left below illustrates in a way how light radiates from a source S, according to the wave theory. The straight lines drawn from the source are called rays. The circles are called wave fronts. The farther from the source the more nearly a short section of a wave front, for example the section AB, approaches a straight line and the more nearly

![Diagram of wave fronts and light rays]

Fig. 7. Huyghens' explanation of refraction.

two adjacent wave fronts become parallel. The rays too in such a section approach parallelism.

The diagram at the right represents a beam of light made up of parallel rays and parallel wave fronts passing from
air into water.

To explain refraction according to the wave theory, let us think of each wave front in air as a rigid pole carried between two men walking on dry land, and each wave front in water as a rigid pole carried between two men walking in mud. All the men walking on dry land travel at a certain speed and all the men walking in mud travel at another speed. As the two men A and B advance toward the mud, which one will step in it first? This one, A, will be slowed up when he steps in the mud. Consequently, during the time interval in which the speeds of A and B are different, the direction of the pole will change.

However, when both men are in the mud they will both walk at the same speed and the column of men walking in mud will be a straight line.

According to Huyghens' theory, does light travel faster in water or in air? How did Newton answer this question (see p.172)?

The Crucial Differences Between the Corpuscular and the Wave Theories. After the deaths of Newton and Huyghens, the argument continued. It hinged around the following three crucial questions which only scientific research of the future would answer:

1. Does light travel faster in the denser of two mediums as proclaimed by Newton, or slower as proclaimed by Huyghens?

2. Does light bend around a corner as proposed by Huyghens and denied by Newton?
3. Is there an ether as assumed by Huyghens and ridiculed by Newton?

What was the outcome? Was Newton, the pride of England and one of the greatest thinkers of all time, right? Or was Huyghens, the comparatively unknown Dutchman?

The Experiment that Rocked the Seats of Learning of the Entire World. For nearly a century and a half Newton's theory held sway. Not until 1801 was it seriously challenged. Then Young, a most brilliant young English physicist—known as "Phenomenon Young" at Cambridge—performed one of the most astounding yet simple experiments of all time and as a consequence brought the wave theory back to life. The results shook the seats of learning all over the civilized world.

This simple experiment can easily be understood by referring to the diagram below. S is a screen; A, B, and C are narrow slits in opaque (non-transparent) screens. Light of one color diverges from a source X, passes through A, and on through B and C. According to Newton's theory how many bright lines should appear on the screen?

Fig. 8. Does light bend around a corner?

Instead of two lines as would be predicted according to Newton's theory, several bright and dark lines appeared on the screen as shown in the diagram at the right. Both bright
and dark lines appeared directly behind the part of the screen separating the slits B and C, thus proving conclusively that light will bend around an obstacle. But how are the dark and bright lines explained? Does Newton's theory account for them? Does the wave theory? Or is another theory needed to explain them?

**How the Bright and Dark Lines Are Explained.** In the study of sound, you learned that when two sound waves of the same frequency and amplitude are superposed, one on the other, there is interference. When the waves are in phase, that is rarefaction on rarefaction and condensation on condensation, the result is constructive interference or reinforcement of sound. When the two waves are out of phase, that is rarefaction on condensation, the result is destructive interference or silence.

If we assume that light is a wave motion, we can likewise account for the bright and dark lines. The bright lines 1, 3, 5, etc., are caused by light waves coming from C reinforcing those coming from B. The dark lines 2, 4, 6, etc., are caused by light waves coming from C interfering destructively with those coming from B.

Since Newton's theory would not explain interference, and since the wave theory explained everything else as well as did the corpuscular theory, one would expect, as Young expected that the wave theory would soon become dominant. But such was not the case. There were die-hards in those days, people who would not face facts, just as there are today.

The renowned Marquis de La Place, of the French Academy of Science, was bitter in his opposition, as were many other
scientists. This, of course, can be understood when one realizes that the followers of Newton looked upon his opinion as authoritative, everlasting, and never-changing knowledge, and that most people never accept a new idea that causes them to change their opinions and ways of thinking.

Unable to understand Young's work, Lord Broughham, editor of the Edinburgh Review, was vicious in his attack; asserting that he could not find in Young's scientific papers anything, "which deserves the name either of experiment or discovery" and he took the Royal Society to task for printing such "paltry and unsubstantial papers." Of course the tragedy was that few people had a chance to read Young's papers, but they had the chance and did read the Edinburgh Review. Can you think of like instances, perhaps in other fields, today?

An Interference Experiment: Place two pieces of rectangular plate glass, about 4 x 8 cm. each, one on top of the other. Put a rubber band around one end of them to hold them together as shown in the diagram, and between the other ends, put a piece of tissue paper to hold them apart. There is thus formed a wedge of air between the two plates. Now hold this apparatus so that light of one color, produced by burning some common table salt (sodium chloride) in a bunsen flame, is reflected in the plates. As a result, an image of the flame will be seen which is crossed by a series of parallel dark and bright lines. What causes this series of lines?

These lines can be explained by referring to the enlarged diagram at the right. The air wedge is represented by the
space between AB and AC. When the light strikes each surface of the glass it is partly reflected; the rest is transmitted. To explain the dark and bright lines we need to consider only what happens at the surface of the air wedge.

Let ED (full line) represent the wave train of light reflected at E from the surface AB, and let E'D (broken line) represent the wave train reflected at E' from the surface AC. Now, if the distance from E' to E is one-half of a wave length, the wave trains ED and E'D are completely out of phase; consequently destructive interference (darkness) is produced.

At F' and F, where the distance between the plates is equal to a complete wave length, the reflected wave trains F'G and FG are in phase. Should a dark or bright line appear here? Which should appear at M'M?

How Can the Wave Length of Light Be Determined? Those of you who have studied geometry know that the triangles CAB, F'AF, and E'AE are all similar triangles. Consequently, if the dimensions of the large triangle CAB and the side F'A of triangle F'AF are known, then the length of side F'F which equals the wave length of sodium light can be calculated from the proportion.
\[ \frac{\text{CB}}{\text{F'F}} = \frac{\text{CA}}{\text{F'A}} \]

The wave lengths of different colors of light will all differ from each other. And the distance between the bright and dark lines will differ. However, a close approximation of the wave length of light can be obtained from this crude apparatus.

**A Young Frenchman RedisCOVERS Young's Work and Pushes It Forward.** Fourteen years after Young had discovered the interference of light, Fresnel (1788-1827), a young French engineer and mathematician, working in ignorance of Young's work, rediscovered the interference of light. However, when he learned of Young's discovery, his enthusiasm and curiosity were not dampened. Cheered on by Young and Dominique Arago, a fine soul who headed the committee of the French Academy of Science to whom he submitted his work, Fresnel worked with more eagerness and energy than ever, and as a result, he advanced the first complete and fully satisfactory theory of the nature of a light wave.

**What is The Nature of Light Waves?** When we studied sound, the nature of different kinds of wave motion was discussed. In a sound wave, the particles in the medium, through which a wave train is transmitted, vibrate back and forth parallel to the direction that the sound wave travels. Such a wave is called a **longitudinal wave**.

When a wave train is produced in a rope, as we know, the wave train moves along the rope but the particles of the
rope (the medium) vibrate in a direction perpendicular to the direction that the wave travels. This type of wave is called a transverse wave. The question naturally arises, "Is light a transverse or a longitudinal wave?"

In a crystal, such as a diamond, a tourmaline crystal, or a crystal of common table salt, the atoms are arranged in layers somewhat as is shown in the diagram below. Between the layers of atoms are narrow layers of space somewhat like the space between the leaves of this book when it is closed. When light is passed through a crystal of any of these sub-

![Fig. 10. The arrangement of atoms in a crystal of common table salt.](image)

stances there is much evidence to show that it does so by passing through these parallel layers of empty space.

Fresnel found that when two tourmaline crystals are placed one behind the other, so that the layers of space of one crystal are parallel to the layers of the other crystal, then light will pass through them as shown. However, if the layers of the two are at right angles, light will not pass through them.

![Fig. 11. The polarization of light.](image)
To account for this phenomenon, let us assume that light is a transverse wave and the direction of the wave is south. Then the ether particles conducting the wave would vibrate up and down horizontally and in all other directions perpendicular to the direction that the wave travels.

However, when light passes through crystal A, in diagram 1, the space between the layers is so small that few, if any, except the vertical vibrations are transmitted. And as a result, all the vibrating particles in the transmitted light vibrate in one plane. This light is called polarized light.

Explain why, in diagram 1, the polarized light from crystal A passes through crystal B. Explain why, in diagram 11, the polarized light from A does not pass through crystal B.

Can the phenomena, shown in diagram 11, be explained if light is assumed to be a longitudinal wave? If light is assumed to be corpuscles? Does this phenomenon support the wave theory or the corpuscular theory?

It was Avoago who brought the work of Fresnel to the attention of his colleagues at the French Academy of Science with his own personal endorsement. At once a bitter controversy broke out. The opposition was led by La Place and others. The argument lasted for several years; but finally, in 1823, the opposition's hostility, mellowed by time and thought, gave way to reason, and Fresnel was elected a member of the French Academy of Science. Following this triumph, the wave theory came into its own; the corpuscular theory was practically forgotten; and the wave theory moved on to new conquests.
The Speed of Light. One of the crucial questions "Does light bend around a corner?" asked on page 175, has been answered in favor of Huyghens' wave theory. Now let us consider the speed of light.

Aristotle believed that light travels instantaneously from one point to another. Both Newton and Huyghens opposed this theory but neither determined its speed. Why do you suppose they opposed it?

Galileo performed the first known experiment to measure the speed of light. He placed two observers, A and B, several miles apart, each with lanterns. A uncovered his lantern and at the same instant noted the time. When B saw the light from A's lantern he uncovered his lantern. When A saw the light from the lantern of B he again observed the time. The speed of light was calculated by dividing twice the distance between the observers by the difference between the two observed times. However, the errors were so great that no reliable speed was obtained. What did Galileo really measure? Not until 1676 was the speed of light determined. This was done by Romer, a Danish astronomer.

Fig. 12. How Romer determined the speed of light.
It happens that the sun, earth, Jupiter and its moon, Io, as shown above, all lie in the same plane; consequently at certain times Io and the earth are on opposite sides of Jupiter and when this occurs, Io cannot be seen from the earth; that is, an eclipse occurs. Romer determined the time interval between the eclipses when the earth is near \( E_1 \). Near this point the earth is neither moving toward nor away from Io; consequently, light travels from Io to the earth the same distance for each of the two eclipses.

Romer found this time interval between eclipses to be 42 hours, 23 minutes and 36 seconds, and he used it to predict the occurrence of future eclipses. If an eclipse occurred on Wednesday at 4:45 p.m., when should the next one occur?

When the earth was near \( E_1 \) he found his predictions of the eclipses to be correct but when the earth was near \( E_4 \) he found that they occurred 996 (approximately 1000) seconds later than the time he predicted. However, he discovered that the time interval between the eclipses did not change. What could all this mean?

Romer knew that when the earth is near \( E_4 \) it is 186,000,000 miles closer to Io than when it is at \( E_1 \). Could the difference in time be the time required for light to travel 186,000,000 miles? Surely it must be reasoned because if light travels instantaneously this difference in distance should not cause the delay in time. The only logical conclusion that he could make was that the speed of light is not instantaneous and that the delay of 996 seconds was the time required for
light to travel 186,000,000 miles. Therefore, to find the
velocity of light he divided the number of miles (distance)
by the number of seconds (time) \( \frac{186,000,000}{996} \) and found that
the speed of light is a little more than 186,000 miles per
second which is approximately equivalent to 300,000,000
meters per second. For practical purposes this velocity is
the one that is usually used. Then what was it that Galileo
measured?

Not until 1849, was the velocity of light measured over
a short distance as Galileo had tried to do. Poucault and
Fizeau, working independently and using different methods
succeeded in doing it the same year. A description of the
method which each used can be found in almost any college
physics textbook. (Fizeau found that the velocity of light
is 186,290 miles per second and Foucault found it to be
185,800 per second.)

Foucault went further than Fizeau; he measured the
velocity of light in water as well as in air and found that
the velocity is greater in air, as predicted by Huyghens but
denied by Newton. This was the blow that completely felled
the corpuscular theory; at least for the time being.

The Astronomers' "Yardstick." The velocity of light is
so terrific that it is almost beyond comprehension. A
simple calculation shows that in one second light will travel
a distance somewhat greater than seven times the distance
around the earth at the equator. The time required for light
to travel from the moon to the earth is about 1.3 seconds;
from the sun to the earth a little over eight minutes;
from the nearest star to the earth about four years; from Polaris, our north star, about 44 years. If Polaris were destroyed today, how much longer could sailors use its light to guide ships at sea?

The distance which light travels in one year, about six million miles, is called a light year--the astronomers' "yardstick." How many miles away is the nearest star? Polaris? Do you see any reason why astronomers should use such a tremendous length for a yardstick?

**Electromagnetic Theory of Light.** You have already learned that when a current of electricity passes through a wire, a magnetic field is set up around the wire, or the coil; and that when the circuit is broken, the field ceases to exist. If the circuit is made and broken periodically, as is done by the circuit breaker of an induction coil, magnetic pulses are radiated. These are known as magnetic waves.

Maxwell found that these magnetic waves, like light, travel through a vacuum with the same velocity as light. From those observations, he concluded that electromagnetic waves, like light, travel in ether; and that light is electromagnetic waves.

Maxwell also proposed that the origin of light is a vibrating electrified particle which causes ether particles to vibrate the same as a tuning fork causes air particles to vibrate. At that time electrons were unknown. This electromagnetic theory also hinged on the crucial question, "Does ether actually exist?"

**Does Ether Actually Exist?** While still a student at
West Point, Albert A. Michelson (1852-1931) began thinking about this question. Because there is no evidence that the ether is in motion with respect to other parts of the universe, he assumed that if the ether exists, it stands still. And he reasoned that the earth, in moving through it, should set up ether currents parallel to the direction that the earth moves, just as a moving train sets up air currents.

In 1881, Michelson, assisted by Morley, attempted to measure the absolute velocity of the earth with respect to the ether by timing the passage of light a certain distance up the ether stream and back, and the distance across the stream and back. To their surprise, and to the surprise of nearly all the other scientists of that day, they found that the time in both instances was the same. But, if ether currents exist, it should have been different. Why the time should not have been the same in both instances can best be explained if we know the answer to the question, "Which requires longer; to swim a hundred yards upstream and back in a rapidly flowing river or a hundred yards across stream and back?" An experienced swimmer knows it requires longer to swim upstream and back. Why?

Since the time of passage of light in both directions was the same, Michelson and Morley reasoned that there are no ether currents caused by the earth moving through the ether and consequently no ether exists.

Careful repetition of this famous experiment by Michelson, Kennedy, Peaso, and finally Joos in 1931 has shown the absence
of any ether current within the accuracy of the experiment.

This experiment, like Young's interference experiment, shook the whole foundation of physics. First, it cast doubt on the wave theory of light. Why? But this was far from its most damaging blow. The damaging blow was that there is nothing standing still. It was already known that the earth, the solar system and all the stars are in motion; everything is in motion. And since everything is in motion there is no absolute motion; all motion is relative.

The fact that all motion is relative can best be understood by considering the following examples:

Tom is driving his car on the highway and the speedometer reads 35 miles per hour. John is following Tom and, according to the speedometer in his car, is traveling at the rate of 30 miles per hour. However, Tom with respect to John is traveling at the rate of five miles per hour. Suppose they were driving toward one another. What would be Tom's speed with respect to John's? Thus we see that one's rate of motion or speed depends upon what point of reference one refers to.

Or suppose you are sitting in a train that is standing on a track, waiting for another train to pass. When the other train passes can you tell by looking at it whether your train or the other train is moving? No you can't! But you can tell by looking out of the other side of the train at a building. But if all of the blinds on that side of the train are down so that you cannot see out, then you cannot tell which train is in motion.

With respect to the two trains, the building is standing still, but is it with respect to someone on the moon? For the
physicists, taking away the ether which they assumed to be standing still was almost like pulling down the blinds on the one side of the train mentioned above. They had nothing but moving objects to which they could refer motion.

Newtonian physics was based on the fact that motion is absolute. The results of this experiment pulled out one of the foundations of Newtonian physics. However, out of this experiment came another theory, the theory of relativity, which more completely and more fully explains our universe. One of the two assumptions underlying Einstein's special theory of relativity is, "All motion is relative."

The result of the Michelson and Morley experiment was not all that cast doubt on the wave theory of light. Toward the end of the nineteenth century, several new discoveries were made which caused great confusion in the thinking of many.

The Photoelectric Effect. If we allow light to strike polished metal, electrons are ejected from the metal. The ejection of electrons caused by light striking metal is called the photoelectric effect. Evidently, the energy of the light is transformed, or partially transformed, into the kinetic energy of the ejected electrons.

If we allow light of one color (one wave length) to strike metal, all the electrons ejected have the same velocity and thus the same energy. If the intensity of the light source is increased, we would logically predict that the velocity of the ejected electrons would be increased.

However, if we test our prediction by experiment, we
find that the number of electrons ejected per unit of time
is increased, but not their velocity. Are these experimental
data in keeping with the wave theory? With the corpuscular
theory? With either theory? Let us consider the wave theory
first.

In the study of sound we found that an increase in the
intensity of sound causes an increase only in the amplitude
of the waves emitted. If the same is true of light, then
increasing the intensity should increase the amplitude of the
waves; and hence, increasing the amplitude of the wave should
increase the velocity of an electron ejected by it; for the
same reason that a "tall" ocean wave tosses spray higher than
does a "short" one.

That is, increasing the intensity of light should increase
the velocity of the electrons ejected from the metal. But
this is not so. Here, then is a contradiction between experi-
mental fact and the wave theory. Does the corpuscular theory
explain this fact? If not, how shall we account for it?

You will recall (see p. 168) that Newton said if the
intensity of a light source is increased, the number of corpus-
cles emitted per unit of time is increased. However, he did
not say that their velocities are increased. He believed
that the particles making up red, violet, or any other colored
light, all travel at the same velocity.

Since all light corpuscles travel at the same velocity
and all the corpuscles making up light of one color are alike,
then all the corpuscles of, say, yellow light have the same
amount of energy.
Now, if each corpuscle could strike an electron, say, a "head on" blow, or each corpuscle could strike an electron the same kind of a glancing blow, then the electrons that would be knocked out of the metal should have the same velocity providing one electron is as easy to knock out as any other. But such a condition would be highly improbable and contrary to Newton's laws of mechanics.

The Quantum Theory of Light. In 1905, Max Planck, a brilliant German scientist who was granted the Nobel prize in 1919, proposed a theory that appears to account for the photoelectric effect. Instead of light consisting of corpuscles or continuous waves, he said that it consists of bits of energy, bundles of energy, or particles of energy, which he called quanta (quantum singular) or photons. Photons making up light of one color all have the same velocity and energy. Photons of light of one color impinging upon the surface of metal throw out electrons all having the same velocity.

But this is queer, you say. May not one electron absorb the energy in one photon and be thrown out with greater velocity than an electron that absorbs only part of the energy? Or may not some electrons be tossed out easier than others. Why do all the electrons ejected have the same velocity? The theory doesn't make sense, does it?

This is what many scientists thought when Planck presented his theory. Since it was not in agreement with Newtonian physics they laughed at it.

According to Planck an electron either absorbs all the
energy in a photon or none, and only certain electrons will absorb certain photons. As a result all those that are thrown out have the same velocity and hence the same energy.

But you are asking "What does this quantum theory mean? Does it mean that Newton was right after all and that Huyghens, Young and Fresnel were wrong?" No it doesn't! All of them, including Planck, may be partly wrong, because the quantum theory cannot explain either refraction, or interference as easily and as naturally as does the wave theory.

So, seemingly we are right back where we started: with two theories, each surprisingly successful in explaining certain phenomena but neither by itself explaining all the phenomena. Each presents two distinct pictures of light; a particle-energy picture and a wave picture. But scientists have been trying for centuries to get one theory to explain all light phenomena. Can it be done? And can the cause of light be explained? Before answering these questions we will have to solve the riddle of color. This we will discuss in the next Chapter.

No, we are not right back where we started; we have come a long way in this chapter. Out of the electromagnetic theory came radio; out of this theory and the quantum theory came television and many improvements in radio; and out of both theories have come hundreds of improvements and inventions which make man's lot on the whole easier. All this shows what man's intelligence is capable of accomplishing when allowed to work unfettered.
CHAPTER VII
MEASURING THE RESULTS OF TEACHING

Almost every teacher has heard the statement, "He who writes the tests determines what is taught and how it is taught." This statement is thoroughly in keeping with the relativity point of view, that the acts of an organism are such as to enable it to reach its goal or goals in the quickest and easiest way it comprehends. The following examples illustrate how tests can determine what is taught, and, to a large degree, how it is taught.

In the school system where the author was employed for a number of years, the Emporia All-Pupil Scholarship Tests were given near the end of each semester. The tests were the so-called objective tests—true-false, multiple-choice, completion and matching. They tested mostly for the ability to recall facts, to use skills and to apply principles.

The administrative officers were prone to rank teachers in accordance with how well their pupils did on the respective tests. Under such conditions, it is only natural that a teacher interested in keeping his job or being promoted, will try to devise ways and means to insure that his pupils will do well.

To do this, the writer and an associate, as did many other teachers in the system, obtained copies of all the tests that had previously been given in the particular subject which we taught and selected from these tests every different type of question that was included. Then we made up three more
questions of each particular type and mimeographed all of them. As a result, we had a total of about five hundred questions over each semester's work.

In teaching, we gave these questions special emphasis, and about ten days before the tests were given, we gave each pupil a copy of the five hundred questions. During the next several class periods we spent most of the time drilling pupils to answer these five hundred questions. Our main objective was to teach pupils to pass tests; to recall facts and apply principles.

In the State of New York, the Regents Examinations are given each year. For a pupil to pass his grade, he must pass these examinations. In many schools, teachers are ranked according to how well their pupils do on these examinations. From knowledge of previous examinations, teachers know the type of questions which will be asked. The result is that teachers teach pupils to pass examinations.

In many school systems, standardized achievement tests are given. Since teachers want their pupils to make as good showing as possible, it is only natural that they will prepare pupils to answer the questions which they know will be asked. Tests of this kind have a great influence on what is taught and how it is taught. Teachers are human, like everyone else.

According to Tyler, the most widely used standardized test is the Stanford Achievement Test, given to about two million grade-school pupils in America each year. This test
consists of ten sets of exercises which test for: skill in reading, understanding and meaning of words, ability to spell words when writing from dictation, choice of words to complete unfinished sentences, recall of persons and events in literature and other "classics," recall of historical facts, recall of geographic facts, recall of physiological facts and rules in hygiene, skill in solving verbal arithmetic exercises and skill in the mechanics of arithmetical computation.

Achievement tests of the same kind are given in the secondary schools. The Sones-Harry High School Achievement Test is a good example and is used widely.

Such tests are designed to examine mainly for skills, recall of facts and application of principles—the end-products of education in most schools. The kind of teaching for effecting such end products was discussed in the latter part of Chapter II and in the early part of Chapter V. A number of reliable and valid standardized tests have been published to determine achievement in almost every subject of school curricula.

As has been stated a number of times, the relativists end-products of education are not only the enhancement of a pupil's outlook on his world, but are also harmonization of his outlook and the development of independent learners. Very few reliable tests for the latter two end-products have been written, and only within the past few years has any work been done in developing such tests. Here is a large field for future research and study.
The author has written a few unpublished tests, designed to test for harmonization of a pupil's outlook on his world. The following are a few sample questions:

Mark the following true or false.

1. Science is a tool which man can use to control his environment.

2. Man should make every effort to control his environment rather than let his environment control him.

3. When a person becomes ill, a good thing to do is take a laxative.

4. We should not try to solve our economic problems through study, legislation, and experimentation; because, if we just leave things alone, God and the Law of Supply and Demand will solve them for us.

5. A patient with appendicitis should never take a laxative.

In this list of questions there is a conflict between one, two, and four; and between three and five. Many such statements can be formulated for determining attitudes, and discovering conflicts in pupils' thinking.

In 1924 F. D. Curtis\(^1\) did some pioneer work in determining Scientific Attitudes. Hartung, Noll, Downing, Tyler and several others have made similar contributions. Curtis' test consisted of 34 exercises which were intended to determine (a) conviction of universal cause and effect relationships,

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\(^1\) Curtis, F. D., Some Values Derived from Extensive Reading of General Science, Teachers College Contributions to Education, No. 163, Teachers College, Columbia.
(b) habit of delayed response, (c) habit of weighing evidence and (d) openmindedness.

The following are a few examples:

1. A little boy is looking over a board fence so that only his head is visible. The fence is five and one-half feet high and the little fellow's head is six inches above the top of the top of the fence. How tall is he?

25. A new kind of fruit jar is advertised. A woman decides to give it a trial and buys one. But the fruit she cans in it spoils, and she, therefore, concludes that the new type of jar is not a success.

Noll's test was a device to measure scientific attitudes. These included open-mindedness, suspended judgment, accuracy, understanding of true cause-and-effect relationships, intellectual honesty and criticalness. The test does not depend on knowledge of science. It aims to measure attitudes employed in everyday situations, and is based on the theory that unless the scientific attitude of mind is carried from the classroom into every day situations, it is of little value.

Several other tests of this kind have been published and no doubt they are all steps in the right direction. However, all of them test only a pupil's ability to demonstrate on paper his knowledge of and ability to apply certain tricks or techniques. In no instance do they test whether a pupil actually will apply the method of science when faced with a problem situation.

According to the Commission on Secondary Education of the Progressive Education Association,
It is quite clear that written examinations, whether of the essay type or of the objective or "new" type, are not adequate for obtaining all the evidence on the basis of which evaluation should be made. Other methods will also be required;...

The methods which the Commission proposes are (not direct quotations):

1. Anecdotal records by teachers, parents and students. This consists of an objective description of student reaction and of the setting in which the reaction took place.

2. Questionnaires

3. Interviews

4. Study of student creative products (experiments, projects and written material).

5. Student diaries of reading and other activities.

The same Commission has done considerable work in formulating tests for a pupil's ability to make use of the following techniques in doing reflective thinking:

1. Ability to discover and define problems.

2. Ability to observe.

3. Ability to select facts relevant to a problem.

4. Ability to collect and organize facts.

5. Ability to draw inferences from facts.

6. Ability to interpret data.

7. Ability to develop logical proof.

8. Ability to apply principles.
   (This includes ability of students to use principles for the purposes of predicting).

On close examination, it is found that the Commission and those collaborating with the Commission have not gone far beyond Noll's and Curtis' tests. Most of the tests which the Commission proposes are designed to measure a pupil's ability to use techniques on paper and pencil tests. Most of the situations devised are one-road situations in which the pupil has no chance to differ or raise objection. The answer is a preordained affair because all answers to be considered by the pupil are previously formulated by the test makers, and only one will be considered correct. The tests therefore afford the examiner no way of knowing how a pupil arrives at a conclusion. Thus answers instead of the method are emphasized.

The following is an example:

Directions: In each of the following exercises some test, experiment or situation is described. Below the description you will find several statements which are suggested as possible interpretations of the data. Assume that the facts of the description are accurate. Carefully consider each of the statements and indicate in the columns to the right whether you believe

(1) The evidence is sufficient to make the statement true.
(2) The evidence is sufficient to make the statement false.
(3) The evidence suggests that the statement is probably true.
(4) The evidence suggests that the statement is probably false.
(5) The evidence is insufficient to make a decision concerning the statement.

Problem 1.

Dextrose is an extremely unusual product. It is the sugar of the blood; the fuel that furnishes energy for every muscular effort. It can be injected directly into the blood stream where it is utilized exactly as though it were put there through the regular digestive channels. Dextrose is the final nutritive product of the digestion of all starches and sugars and is the only sugar present in significant quantities in the blood of general circulation. Consequently, when it is taken by mouth, it requires no digestive effort and furnishes fuel in a minimum of time. Anhydrous dextrose which is 99.999 per cent pure is now being produced at a cost of less than five cents per pound.3

<table>
<thead>
<tr>
<th>Statements</th>
<th>'(1)'</th>
<th>'(2)'</th>
<th>'(3)'</th>
<th>'(4)'</th>
<th>'(5)'</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Athletes should eat dextrose before engaging in extreme competition</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
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<tr>
<td>b. Dextrose is used in building up the body</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>c. Dextrose may be used to feed people who are unable to take any food into their stomachs</td>
<td></td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>d. Dextrose is an extremely scarce substance</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
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<tr>
<td>e. People who eat dextrose are apt to be more nervous than those who do not</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>f. It is difficult to produce pure dextrose</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>g. Dextrose is easier to digest than any of the other sugars</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>h. Doctors find dextrose to be a valuable aid in the treatment of certain disorders</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
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<tr>
<td>i. The use of dextrose leads to an excessive amount of waste elimination in the body</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
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<tr>
<td>j. Dextrose has a higher fuel value than sucrose (cane sugar)</td>
<td>✔</td>
<td>✔</td>
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The above test, like all the others discussed, seems to test only a pupil’s ability to apply skills. Ability to hypothesize, test hypotheses, and choose a hypothesis which best harmonizes all data are not determined. Neither harmonized outlook nor ability and desire to solve problems by reflection-level study are tested for. Such a test Bayles believes would be something of the following nature:

First, it may include a written essay in which the student is given a single challenging problem—one which really causes him to pause for reflection, to consider alternative answers, to marshal and organize the information which he possesses, and possibly to find new information. He should be given sufficient time to write a comprehensive answer; more than a single class period if necessary. Such a paper should be judged upon three bases: first, whether or not all reasonably available and pertinent data have been taken into account; second, whether or not the conclusions are in agreement with the data that are being considered; and third, whether or not the conclusions are in agreement with other conclusions known to have been accepted by the student. Such a paper should not be given a low mark merely because the conclusions fail to agree with those of the teacher or with other generally accepted conclusions.5

In testing for reflection-level or scientific thinking, above everything else the pupil must know that he is not required to arrive at a preordained answer. If he believes he must do so in order to get a grade, then an obstacle is put in the way of scientific thinking and in the way of a desire on the part of a pupil to do scientific thinking. A pupil

should be made to understand that educationally, the method of arriving at answers is of much greater importance than the answer itself. Until teachers realize this fact, little if anything can ever be done in the way of developing independent learners.

Besides the paper and pencil test suggested by Bayles, there are other situations which serve as tests for reflection-level thinking. For example, in the study of baking powder previously discussed, there was a variety of problems that had to be solved; many of which require reflection-level thinking. The same was true of the study of conditions necessary for living things to live (see p. 80). Whether a pupil could devise experiments to solve these problems, gather data, weigh data, test conclusions and arrive at a conclusion in keeping with the data would all be indicative of a pupil's ability to solve problems by the method of science and to do scientific thinking. These are the criteria to use for determining a pupil's grade.

Other tests are the pupil's attitude in the classroom and outside. Does he tackle problems earnestly, thoughtfully, and seriously when he considers them worth tackling? What types of problems does he consider worth solving? How quick is he to sense problems when he meets them? Does he jump to conclusions, or is he slow to become convinced? Is he bull headed and argumentative, or is he wishy-washy and perfectly willing to accept any conclusion just so it relieves him of
responsibility? Is he tough minded, yet glad to consider all points of view? Which is of greater concern to him: Who is right, or What is right?

The real test of a program which aims to develop independent learners, who are ever enhancing and harmonizing their outlook on life through reflective study, can be carried out only over a period of years and by studying the effect on individuals as well as the effect on the community as a whole. Does it change the attitude of older as well as younger members of the community toward problems which face them? Do they attack their own personal problems in a scientific manner? Do they attack problems of the community in a scientific and democratic manner? Do people meet in open public forums and discuss the pros and cons of problems which face the community and the nation? Do they organize study groups and classes in adult education to study such problems? Once a thorough study has been made, do they willingly act on the basis of conclusions reached?

Does the school program develop better buying habits and attitudes? Do people demand facts about the products which they buy rather than promises and claims? Do they read labels? Do they check weights and measures? Do they buy in quantity and in the bulk rather than in small quantities?

Does it develop a demand for better radio programs and higher class of advertising over radio and in newspaper? How does it affect the reading habits of the people in the community as shown by books and periodicals bought in the home and
checked from the school and public library? In forums and other places, when public addresses are given, do people insist that speakers define terms, state fundamental assumptions and make clear their points of view?

The answers to such questions as the above do not provide objective evidence as to whether a school program designed to develop independent learners is actually succeeding. Devising such tests affords a great opportunity for the research worker of tomorrow in the field of tests and measurements.
Conclusions. Like all other theories in education, the relativity theory of education is in no way ultimate or final. However, like the relativity theory of physics, it has opened up new vistas for study and experimentation. Only through study and experimentation will the theory be refined or finally rejected.

In formulating the special theory of relativity, Einstein started with two assumptions and tried to determine by logical deduction what they imply as to the nature of the universe. The two assumptions were his taking-off points; his fixed guide posts. Everything deduced, implied, or predicted had to agree with these two assumptions and had to stand the experimental test. If any new knowledge had been discovered which stood the experimental test but did not agree with the two assumptions, Einstein would have had to modify his assumptions in order to bring about internal agreement. Harmony or agreement of assumptions and data, and the experimental test of predicted data were his two guides for knowing right from wrong.

Democracy and science carry within themselves provisions for their own revision; they carry within themselves their own guide posts and provide their own ways of knowing. Democracy and science do not depend upon outside authority for knowing what is right and what to do.

In writing this thesis, we have made a special effort to point out the fundamental assumptions of each discussion. Also,
we have tried to discover by logical deduction the implications of these assumptions for teaching. For example, in Chapter II we listed the fundamental assumptions of behaviorism; in Chapter III we listed the fundamental assumptions of the goal-insight theory of behavior and learning; and at the end of each of these chapters we discussed the implications of the respective assumptions for teaching.

Among the listed assumptions which have bearing on the relativity theory of teaching, there is much overlapping. By eliminating most of this we have reduced the assumed propositions to three basic assumptions and eight postulates. The postulates can all be deduced from the three assumptions.

The first assumption grows out of Chapter I, the second out of Chapter III, and the third out of Chapters IV and V. The first takes precedence over the other two. The basic assumptions are:

1. A thing, in and of itself, has no meaning. Meaning of a thing depends upon the relationships which an observer senses between the thing and other things.

2. Behavior is purposive.

3. The common man is capable of shaping and guiding his own destiny.

The postulates are listed below. Because the assumptions from which they are deduced are so closely inter-related, no attempt will be made to indicate from which assumption a particular postulate is deduced.

1. Truth is relative; it changes as new relationships are sensed.
2. In a democratic society, the dignity of man and the importance of allowing each to develop his personality to the maximum, on a fraternal basis, are of prime importance.

3. A large majority of the adult population, if educated*, is capable of assuming the responsibilities of democracy.

4. Democracy**, as a way of life, is dependent upon having the methods and means of production under control of the people, and upon having a wide distribution of economic and other advantages accruing from the democratic life.

5. Both democracy and science are intellectual tools which are of special value to man in shaping and controlling his world. Both require a free intellect and both are evolutionary; not revolutionary.

6. The real problems which confront people in a democracy require reflection-level study for solution.

7. Nearly all pupils, if properly trained, are capable of doing reflection-level thinking. However, they may differ widely in the degree of capability.

8. Teaching procedures should be in keeping with democracy and the method of science.

Certain persons, who read this thesis before it was in its final form, asked why we have not set up definite goals and why we have not made a "blueprint" for teaching. Our whole theory forbids such!

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*Note: For the definition of education see (p. ).

**Note: For the definition of democracy see (p. ).
We have set up one goal, or covering-end, for education—the development of independent learners who continually enhance and harmonize their outlook through reflective study of conflicts and problems of their world. This goal was deduced from our assumptions and postulates. It was not taken "out of the blue."

In formulating a theory in science, mathematics, education, or any other field, every effort should be made to keep the number of assumptions at a minimum. The fewer the better. However, as many hypotheses may be formulated as human minds are capable of making through rigorous logic. But, all predictions and implications of a theory must be subjected to exacting experimental tests, and each theory as a whole must be kept consistent. Again we repeat that the two guides in science are experimental tests of data and internal consistency of theory.

When one picks goals out of the blue, so to speak, one calls on outside authority for knowing what is right and what to do. If one goal can be obtained in such a manner, why can not two, three, or even a hundred be obtained? And since each teacher has a different set of prejudices, then each teacher should have a different set of goals. Such methods put education right back in the dilemma, from which we have been trying to escape. Such a system of setting up goals provides no way of knowing from within what is right and what is wrong.

If we are to be scientific, goals, methods of teaching, and all details for teaching must be deduced from the basic
assumptions and must be subjected to the most rigorous experimental practices. And the assumptions must be continually checked and re-checked, especially if new discoveries are made which do not agree with them.

In this thesis, our purpose has been to set up the assumptions of the relativity theory and to consider their major implications for teaching science. All proposals are theoretical and need to be checked experimentally. In making the following recommendations we wish to devote most of the space to what we believe should be done in the way of future study and experimentation.

Recommendations. In order to find problems for study and experimentation, we should look to the predictions which the theory implies, to questions implied by the assumptions, to differences between the relativity theory of teaching and other theories, differences between practices implied by the relativity theory and practices now commonly in use, and to questions raised by the critics. This we propose to do mainly by studying the propositions on which the theory is based.

The first assumption, that, "a thing, in and of itself, has no meaning, and that meaning depends upon sensed relationships," implies that the more relationships one senses, the more meaningful a thing is. This in turn implies that different points of view should be presented in teaching, and that to teach what is wrong and why it is wrong is as important as to teach what is right.

The behaviorists, and other one-answer pedagogues, do
not agree with these implications. Here is a controversy which can be resolved only by further study and experimentation. What might be done will be discussed when postulates six, seven, and eight are considered.

The second assumption, that "behavior is purposive," is one with which the behaviorists do not agree. Data which support this assumption, along with its implications for teaching are discussed in Chapter III. Without question, the burden of proving this assumption lies with the psychologists. All of its implications for teaching are open to further study. If the method of teaching implied does not work in practice, great doubt will be cast upon this assumption. Therefore, one way to test this assumption is to test by experimental practice the theory of teaching implied.

The third assumption, that "the common man is capable of shaping and guiding his own destiny," is questioned by many the world over. This is a fundamental assumption of democracy. An attack upon it is an attack on democracy. One cannot believe in democracy and disagree with this assumption.

Democracy is a theory which is being tested by experiment. Teachers should give the experiment a chance to succeed by using methods which are in keeping with it. Teachers should not sabotage democracy, either by indoctrinating for or against it, or by using other methods of teaching not in keeping with it. Every teacher should have a thorough understanding of democracy; of its implications for modern society and for classroom procedures.
Now let us consider the postulates.

The first postulate, that "truth is relative and changes as sensed relationships change," grows out of the first two assumptions. This does not imply that to be relativistic in thinking one should be vague and inexacting. Instead, it implies that one should be highly definite and exacting.

In Chapter I, we pointed out that two absolutists, one in a moving train (velocity constant with respect to the track) and the other standing beside the track, could never agree, if they were consistent, as to the "true" nature of the path of a ball dropped in the train. One would swear the path to be a straight line, the other would swear it to be a curved line (a parabola).

The implications of the postulate, that "truth is relative, and changes as sensed relationships change," are that both in school and out of school teachers should insist on exacting definition of terms, on clear statement and explanation of assumptions, and on full and precise statements of various points of view and the implications of each. Many of the conflicts in education, politics, religion and other fields would soon cease, if only this were done.

Another implication of this postulate is that education is a continuous process; continual reconstruction of old and new, each in the light of the other. Whether science should be taught so that pupils obtain the final and last word at the outset, or so that pupils are continually reconstructing beliefs and habits of thought and action as new data are presented, is a question about which there is much dispute.
in science education. Whether the assumption, "that truth is relative and undergoes change as new data are developed," stands or falls, depends upon whether the theory as a whole works out in practice.

Postulate two, that "in a democratic society the dignity of each individual, and the equal opportunity of each to develop his personality to the maximum on a fraternal basis, are of prime importance", and postulate three, that "a large majority of people, if educated, is capable of assuming the responsibilities of democracy", are both part and parcel of the democratic philosophy. The fate of democracy will determine whether these stand or fall. Many may differ with the definition of education, and many may question the fraternal basis for opportunity. These assumptions should furnish many opportunities for further study.

Postulate four, that "democracy is largely dependent upon having the methods and means of production in the control of the people and upon having wide distribution of the economic gains accruing from the democratic life", is an assumption that is severely attacked. However, at no time in history, to our knowledge, has widespread democracy existed when the means and methods of production have not been in the control of the people. Can there be any real question that an attack on this assumption is an attack on democracy?

The fifth postulate, that "democracy and science are both intellectual tools of special value to man in shaping and controlling his world, that both are dependent upon a free intellect, and that both are evolutionary, not revolutionary," is
questioned by many. This assumption, too, is part and parcel of the philosophy of democracy and science. The fate of democracy probably will determine whether this assumption stands or falls.

Postulates six, seven, and eight, that "pupils are capable of making reflection-level studies of subject matter", that "problems which confront people in a democracy are problems which require reflection-level thinking for solution", and that "teaching procedures should be in keeping with both science and democracy", are propositions which are severely attacked.

The critics' two main arguments against them are that only pupils with the highest of intelligence are capable of profiting from the problem-solving method of teaching and that pupils taught by this method neither learn facts nor develop proper habits. To prove or disprove these arguments calls for careful and accurate experimentation. Some work has been done already.

Trefz used the problem-solving method in teaching 40 sixth graders. At the beginning of the study, group intelligence tests and the Metropolitan Achievement tests were given. The high I. Q. was 143, the average was 97, and the low was 69. Twelve I. Q.'s were in the normal range, ten were above normal and eighteen were below.

Five months later, Forms B of the Achievement tests were given.

Those whose I. Q. lay in the range of normalcy for their grade made an average of ten months advancement in the five
months between tests, those whose I. Q. lay in the above normal group made seven months advancement and those in the "below normal group" made an average of nine months advancement.¹

One cannot make sweeping conclusions from Mrs. Trefz' study because it represented only one class and was merely preliminary to a longer, more careful study which will be carried on during the coming year. After making a definite and conscious shift of the intellectual level of her teaching from the lower to the higher capacities of her class and making her teaching definitely reflective, Trefz noted a decided pick-up in interest among all pupils in the class; among pupils of low, as well as medium and high intellect. Parents also evinced marked interest.

As to learning subject matter, data from the Metropolitan Achievement tests showed almost twice as much improvement for low and median groups as would normally be expected, and almost fifty per cent greater than normal improvement for the high group. It should be noted that this was a class of forty sixth-graders in a mid-western industrial town of 15,000 population.

A study is to be reported by Burke in a forthcoming master's thesis (University of Kansas) of an attempt, extending over a two-or-three-year period, to conduct an opportunity school in the intermediate grades on the basis of problem-solving method of teaching; I. Q.'s range mostly in the sixties and seventies. Comparisons are being made of the results

¹ Trefz, Ida G., unpublished report of a study at the University of Kansas (1940).
of instruction before and after the change. Final findings are not yet computed, but it appears that they will present clear evidence of advantage to the reflection-level method, both in attitudes and in subject matter accomplishment, as well as in rise of I. Q., on the part of distinctly low-grade mentalities.

Droll used the problem-solving method in teaching 21 pupils in a course in government. The I. Q.'s according to the Schrammel-Frannan Revision of the Army Alpha and the Terman Test ranged from about 124 to 90, with medians of 102 and 101. At the beginning of the study the class medians in both the Civic Information and Civic Attitudes Tests closely coincided with the standardized medians of these tests.

After about three-fourths of the one-semester course had elapsed, the Emporia Scholarship Contest examination in civics was given. On the basis of 3,277 examinations given, all of the members of Mrs. Droll's class ranked above the 65-percentile. During the seventeenth week of the course the Brown-Woody Civics Test was given. All members of the class ranked above the 65 percentile, except one who made a 51-percentile rank score. The median for the class on this test was above the 90-percentile. Informal tests to furnish evidence of general carry-over to out-of-class activities of modified outlook on life and of ability and disposition to treat problems reflectively showed definite gains of the class members over their own records of the previous semester and over non-members of the class. The informal tests included such matters as number of periodicals checked from the library
by students, historical and biographical books read for 
credit in English classes, editorials and feature articles 
related to government appearing in the school paper, radio 
programs and current events given special attention by class 
members, etc. Since no satisfactory tests, formal in nature, 
of reflection-level ability have yet been devised, none 
could be used.

Ulmer\(^2\) has done, in geometry, a thorough and elaborate 
job of determining whether pupils of all I. Q. levels are 
capable of profiting from reflective study, and whether teachers 
can teach under normal classroom conditions in such a way as 
to cultivate reflective thinking without sacrificing knowledge 
and understanding of subject matter.

The experiment was conducted in seven high schools in 
Kansas. Ten teachers and 1,239 pupils participated. An 
experimental group and two control groups were used. In the 
experimental group, emphasis was placed upon reasoning in 
both geometric and non-geometric situations. In one control 
group, geometry was taught without this emphasis. The other 
control group was composed of pupils not studying geometry.

The results of the final reasoning test are shown below.

<table>
<thead>
<tr>
<th>Group</th>
<th>I. Q.'s Less than 100</th>
<th>100-119</th>
<th>120 &amp; higher</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experimental Group</td>
<td>24.2</td>
<td>25.2</td>
<td>30.7</td>
</tr>
<tr>
<td>Geometry Control Group</td>
<td>5.0</td>
<td>8.3</td>
<td>13.4</td>
</tr>
<tr>
<td>Non-Geometry Control Group</td>
<td>5.1</td>
<td>5.1</td>
<td>4.0</td>
</tr>
</tbody>
</table>

\(^2\) Ulmer, Gilbert, Can the Teaching of Geometry Aid in 
Cultivating Reflective Thinking? University of 
Kansas Bulletin, 1940.
Because of lack of uniformity in the content of courses, a scientific comparison of subject matter learned by the geometry control group and by the experimental group could not be made. At the end of the study the ten teachers of experimental classes were asked, "Do you believe there was any loss in the understanding of geometric relationship because of the attention directed to clear thinking outside of geometry?" Nine replied "No." One said there was little or no difference.

In his conclusions Ulmer says:

The results of this study indicate that it is possible for high school geometry teachers under normal classroom conditions to teach in such a way as to cultivate reflective thinking, that this can be done without sacrificing an understanding of geometric relationships, and that pupils at all I. Q. levels are capable of profiting from such instruction. The results also indicate that even what is commonly regarded as superior teaching has little effect upon pupil's behavior in the direction of reflective thinking unless definite provisions are made to study method of thinking as an important end in itself.3

Before any conclusive conclusions can be reached, further experimentation must be resorted to. But, as has been shown, there is considerable proof that pupils below average intelligence can profit from reflective study to a much greater extent than they commonly do from traditional study.

For the sake of argument, suppose we assume that many pupils are not capable of reflective study. What difference does it make as far as learning factual knowledge and other end-products of traditional education are concerned? Few can honestly say that a pupil studying the chapter "What
is Light?" will not learn as many facts as by studying the same question in one of the several textbooks now in use. The only possible reason that can be advanced for thinking otherwise is that the subject matter is more difficult in Chapter VI than in the textbooks. Whether this is true is doubtful. In reaching a decision one way or another, one should take into account that Chapter VI has not been edited by a professional staff of editors, as comparable material in textbooks is supposed to have been.

In comparing Chapter Six with textbooks in use, one should not forget the element of suspense; that is, the problematical situation exemplified. Once a pupil discovers the conflict between the theories, he wants to know which theory is going to win out. The situation is analogous to a mystery story. The subject matter is psychologically arranged, in that it is arranged as growing minds have actually learned it.

Furthermore, "it is logically arranged. Note how each problem logically grows out of the preceding one. The development* represents a "psychological approach to logical organization."

The interest which grows out of problematical situations cannot be lightly dismissed by critics. Some may say that the element of suspense is not great enough to cause a pupil to want to read the whole chapter. Perhaps this is true,

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*The development in most respects closely follows the historical development of the ideas treated.
but the writer does not claim to be a brilliant or even a mediocre writer. However, let a Paul DeKruif, write the same material and "point up" the element of suspense; let a writer put real drama into this story; then let us see what happens to the learning of facts and to the development of habits and attitudes. This would make a glorious experiment.

Another point on which the relativity theory is severely attacked is that by reflective study alone "proper" attitudes, habits, conduct, and emotional feeling will not be attained. Of course, the question which arises is, "What is meant by "proper"? Does "proper" mean that the pupil is to conform to society as it is, or does "proper" mean that the pupil is to be governed by a desire to further democracy and to better himself and society through reflective study?

We assume that the critics mean by "proper" habits the ones which the teacher or other authority decides upon. If the teacher is a pacifist and slightly "pink," he will insist upon one set of habits and attitudes. If he is a hide-bound conservative, he will insist upon a different set. Knowing right from wrong is all based on opinion, which in turn, is based largely upon prejudices.

The critics assume that insight and purposeful habits, developed through scientific study, are not enough to offset the "beast" in man; to overcome his emotions. For this reason children must be taught to make mechanical responses in many situations. That people are not intelligent enough to react as they should in all situations, a relativist grants. For example, a young child who has just learned to walk, if turned
loose on a porch, may walk off. But a child, who has learned
the consequences of falling off a porch, does not go near the
edge. To prevent an accident prior to the development of
insight, a railing or fence should be put around the porch
or the child should not be allowed on the porch by himself.
After the child matures sufficiently in insight and intelli-
gence, he will understand what not to do.

In the adult world if people do not know how to act to
the advantage of their own welfare, then they must suffer
the consequences of their acts. However, we believe that
action with forethought and realization of consequences of
acts will cause far less suffering than blind mechanical
action.

To us, it seems that the world needs people with more
insight than the people of the past and present. Statesmen,
and other politicians, have blindly followed the old thought
patterns for hundred of years; and as a result there have
been wars in nearly every generation. Whether insight,
intelligent habits, and harmonized outlook on life, gained
through scientific study, are enough to guide man's
behavior, is an open question. Onething, of which we are sure,
is that such a guide has never been consistently and persistently
used except by scientists in the study of science. Why not
try out such a guide on a grand scale?

Summary. In this study, we have tried to point a way
out of the confusion that exists in education and Western
culture. With respect to social control in the class-
room and elsewhere, we have endeavored to avoid the authori-
tarianism of autocracy on the one hand and the laissez-faireism of anarchy on the other hand. In science, we have endeavored to resolve the dualism of idealism and materialism and to show how to avoid the pitfalls of idealism, materialism, and scientific materialism. Also, we have tried to show that neither science nor democracy depend upon outside authority for knowing wrong from right and for knowing what to do next.

In education, we have tried to resolve the conflicts between discipline, between interest and effort, and between the many other dualistic conflicts in education today. Furthermore, we have tried to develop a program for teaching science that is in keeping with science, democracy, and scientific education without bringing about a revolution in the organization of subject matter and school administration.

Since the opening sentence of this thesis was taken from the opening sentence of Dewey's "The Quest for Certainty," what can be more appropriate than to close with the last paragraph from the same book?

In speaking of the present office of philosophy, Dewey says:

It has to search out and disclose the obstructions; to criticize the habits of mind which stand in the way; to focus reflection upon needs congruous to present life; to interpret the conclusion of science with respect to their consequences for our beliefs about purposes and values in all phases of life. The development of a system of thought capable of giving this service is a difficult undertaking; it can proceed only slowly and through cooperative effort.  

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APPENDIX I

BIBLIOGRAPHY

In this bibliography all books are listed from which quotations have been taken. A few of the many other books read are also listed.
BIBLIOGRAPHY


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APPENDIX II

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This list includes all of the periodicals from which quotations have been taken, and it includes a few of the many others read.
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APPENDIX III

AN ILLUSTRATIVE EXAMPLE

WHAT IS THE BEST BAKING POWDER?
WHAT IS THE BEST BAKING POWDER?

This problem really arose in a home economics class when the teacher said that "alum" in baking powder is unhealthful and gives the baked product a bitter taste. And she recommended the use of Royal or Rumford, both of which are much more expensive than the so-called alum baking powders.

Several pupils in the home economics class were taking second semester chemistry and so they asked for the chemistry teacher's opinion about the question. The mothers of several of the girls were at the time using alum baking powders seemingly without experiencing the results claimed by the home economics teacher. But there were a few pupils in the chemistry class who were in agreement with the home economics teacher. One girl said that her father could tell on first taste a biscuit or cake baked with alum baking powder and would refuse to eat it. After a little investigation the teacher found that housewives are about as prejudiced and superstitious about baking powder as rural folk thirty years ago were about planting potatoes in the light or dark of the moon.

A boy in the class, after the study was over, strongly insisted upon his mother using a different brand of baking powder. Both parents became very indignant and threatened not to allow the pupil to attend school unless he ceased insisting that his mother use a different brand of baking powder. Several other very interesting situations arose.

One reason for presenting this problem is to show how problems which grow out of one field can be solved in another.
And how chemistry and other fields of study can be integrated without doing away with subject matter fields. This problem also shows how easy it is to run into a blind alley out of which problems in chemistry do not grow unless the teacher is on guard. The problem does serve as an introduction to qualitative analysis and can lead to further work along this line. The problem also raises many implications of science for economics and other social studies. However, it should not be thought that this problem is representative of a whole chemistry course taught in keeping with the theory of teaching advocated. This unit represents a side issue; one which grew out of the main line of thought. It is a type of problem with many social implications that naturally grows out of a course in science.

At the beginning of the study the class decided that in order to make an intelligent choice of baking powders, knowledge concerning the following items should be gained.

1. Composition of the various baking powders.
2. History.
3. Use.
4. Purpose.
5. Purpose of each ingredient.
6. Physiological effect of each ingredient.
7. Physiological effect of residue in the baked product.
8. Healthfulness.
9. Skill needed on the part of the housewife.
10. Consumer's opinion. (see questionnaire).
11. Efficiency.

13. Opinions of experts on health (Doctor's, Dietitians, etc.)


Other questions arose; for example:

"What criteria do people use in buying chemicals such as baking powder?"

"Is price a criterion of quality?"

"If information furnished by advertisers a good criterion?"

"Are nationally advertised brands the best?"

"Is the consumer's testimony of any value in making an intelligent choice of brands?"

To make the study, six popular brands were purchased and analyzed by pupils. The wrappers were removed from the cans and a number was placed upon the can. Thus a pupil did not know what baking powders he was analyzing.

Each pupil was given two brands and was required to make the following qualitative tests:

(a) carbonate; (b) phosphate; (c) sulfate; (d) tartrate; (e) alum; (f) starch; (g) egg white.

The individual findings were combined and the following data were tabulated in each pupil's note book:

<table>
<thead>
<tr>
<th></th>
<th>Sodium Starch</th>
<th>Bicarbonate</th>
<th>Tartrate</th>
<th>Phosphate</th>
<th>S. A. S.</th>
<th>Egg White</th>
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</thead>
<tbody>
<tr>
<td>Calumet</td>
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<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>K.C.</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Royal</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Health Club</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Rumford</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Clabber Girl</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Note: S. A. S. means sodium aluminum sulfate commonly
miscalled alum. To determine the kind of carbonate,
tartrate, etc., the labels were referred to.

From these data each student was expected to make the follow-

ing observations:

1. Starch was present in all the baking powders.
2. Sodium bicarbonate was present in all.
3. Tartrate was found in Royal only.
4. Egg White was found in all but Health Club.
5. Phosphate and S. A. S. were common ingredients of
6. Phosphate only was found in Rumford in the absence
   of S. A. S.

On the basis of all these data, the baking powders were classi-

fied as follows:

1. Tartrate - Example - Royal
2. Phosphate - Example - Rumford
3. Alum - Example - None Sold
   Girl, and Calumet.

The following experiments were performed by the teacher to
demonstrate the reactions of the acid ingredient in the various
types of reactions with baking soda. The last two are "home-
made" baking powders.

1. \[2\text{NaAl(SO}_4\text{)} + \text{NaHCO}_3 \rightarrow 2\text{Al(OH)}_3 + 4\text{Na}_2\text{SO}_4 + 3\text{CO}_2\]
2. \[3\text{CaH}_4(\text{PO}_4)_2 + 8\text{NaHCO}_3 \rightarrow \text{Ca}_3(\text{PO}_4)_2 + 4\text{Na}_2\text{HPO}_4 + 5\text{CO}_2 + 3\text{H}_2\text{O}\]
3. $\text{Hx(C}_4\text{H}_4\text{O}_6) + \text{NaHCO}_3 \rightarrow \text{KNa(C}_4\text{H}_4\text{O}_6) + \text{CO}_2 + \text{H}_2\text{O}$

4. $\text{H}_2\text{C}_4\text{H}_6\text{O}_6 + \text{NaHCO}_3 \rightarrow \text{Na}_2\text{(C}_4\text{H}_4\text{O}_6) + \text{CO}_2 + \text{H}_2\text{O}$

5. Sour Milk + Baking Soda $\rightarrow$ Carbon Dioxide + — — — —

6. Vinegar + Baking Soda $\rightarrow$ Carbon Dioxide + — — — —

If baking soda alone is heated, only part of the CO$_2$ is liberated and sal soda, sometimes called washing soda, is produced which is distasteful. The reaction is as follows:

$$2\text{NaHCO}_3 \cdot \text{heat} \rightarrow \text{Na}_2\text{CO}_3 + \text{H}_2\text{O} + \text{CO}_2$$

The gas evolved was run into lime water which is a test for carbon dioxide. The residues left in the baked product are considered later.

Baking Powder Efficiency Test:

**Purpose:** (a) To determine the amount of carbon dioxide produced by the various baking powders. (b) To determine the cost per ounce of the various brands of baking powder.

**Method:** In this experiment 10 grams of baking powder were placed in a gas generator. Add dilute hydrochloric acid slowly until all the gas is given off. Catch gas by water displacement in a 1000 c.c. graduated cylinder. Each pair of students tested two baking powders. The results obtained were as follows:

<table>
<thead>
<tr>
<th></th>
<th>Vol. gas from 10 gms.</th>
<th>Cost per can</th>
<th>Amt. in can</th>
<th>Cost per ounce</th>
</tr>
</thead>
<tbody>
<tr>
<td>Health Club</td>
<td>865 cc</td>
<td>9 cents</td>
<td>12 oz.</td>
<td>.75 cents</td>
</tr>
<tr>
<td>Royal</td>
<td>833 cc</td>
<td>39 cents</td>
<td>12 oz.</td>
<td>3.25</td>
</tr>
<tr>
<td>Calumet</td>
<td>800 cc</td>
<td>23 cents</td>
<td>16 oz.</td>
<td>1.50</td>
</tr>
<tr>
<td>Rumford</td>
<td>805 cc</td>
<td>25 cents</td>
<td>12 oz.</td>
<td>2.10</td>
</tr>
<tr>
<td>K. C.</td>
<td>850 cc</td>
<td>13 cents</td>
<td>15 oz.</td>
<td>.87 cents</td>
</tr>
<tr>
<td>Clabber Girl</td>
<td>825 cc</td>
<td>10 cents</td>
<td>12 oz.</td>
<td>.85 cents</td>
</tr>
</tbody>
</table>

The baking powder here reported was purchased in Manhattan, Kansas, March 10, 1935.
Conclusions:

1. There was no great variation in the amount of CO₂ given off by each.

2. The cost ranged from .75 cents per oz. (Health Club) to 3.25 cents per ounce, (Royal).

3. The alum phosphate baking powders ranged in price from .75 cents per ounce (Health Club) to 1.50 per ounce (Calumet).

4. The cost of the acid ingredients to liberate an equal amount of carbon dioxide could be arranged in the order of price as follows:
   a. Cream of Tartar
   b. Tartaric Acid
   c. Calcium Acid Phosphate
   d. S.A.S.

Taste Test:

Purpose: To determine if certain baking powders leave a better taste in the baked products.

Method: Two girls from each class baked the biscuits. The baking powders used were Rumford, Health Club, Calumet and Royal. 100 pupils tasted the biscuits.

Data:

This number of pupils thought they detected a bad taste in the biscuits in which the following baking powders were used.

Rumford................. 20 pupils
Health Club............... 20 "
Calumet.................. 24 "
Royal.................... 23 "
All samples tasted the same 24 "
For check purposes seven pupils were given four biscuits each. All these biscuits were made from the same baking powder.

The results were: Three students detected no difference in taste.

Four students detected a difference in taste.

Conclusions

1. No baking powder seemed better than any other baking powder.

2. The imagination seemed to influence the decisions of the pupils.

Questionnaire Sent to Consumers

Purpose: To determine the consumers viewpoint.
To determine the kinds used and results obtained.

Questionnaire on Baking Powder:

1. What kind of baking powder do you use? ____________

2. Why do you use this brand? Check the following reasons:
   a. Cheapest _____
   b. No taste in baked product _____
   c. Recommended by neighbor _____
   d. My mother used it _____
   e. Highly advertised _____
   f. Recommended by grocer _____
   g. Better luck with this kind _____
   h. More healthful _____
   i. Important ingredient made from grapes _____
   j. Double action _____
   k. Takes less _____
   l. Baked product rises better _____
m. Contains no alum
n. Contains phosphate made from bones
o. Bakes faster

3. Have you used any brand of baking powder which had any of the following objectionable features. Name of Brand:

a. Baked product would not rise well
b. Baked product had a bad taste
c. Price too high
d. Had to use too much
e. Objectionable type of advertising
f. Do you think it healthful

Remarks:

Note: This questionnaire was answered by 170 housewives from all parts of the city. Also the opinions of several home economics teachers were obtained.

Typical Answers to Questions:

1. Kind used and why? -- Twelve housewives used K.C. and nearly all checked the following:
   Better luck with this kind.
   Baked product rises better.
   Double action.
   No taste in baked product. Cheap.

2. Have you used any brand which had the following objectionable features? Twelve had used K.C. and checked the following objectionable features:
   Baked product does not rise.
   Bad taste in baked product.
Have to use too much.
Cakes break open.
A Home Economics expert wrote: "I use a cheap alum-phosphate baking powder because the results are the same providing the correct amount is used. It is better to use less of this baking powder. Many housewives make the mistake of using more of the cheaper baking powders when they should use less. One is just as healthful as the other." Space will not permit the tabulations of all the data:

Conclusions:
1. A housewife's opinion is worthless as a criterion for intelligent choice.
2. Many housewives used baking powders because they were cheap.
   Most of the well-to-do housewives used Royal Baking Powder.
3. A number of women are using the various baking powders with good results.

Healthfulness:
Committee on Foods of the American Medical Association are of the opinion that "the alum-phosphate baking powders are just as healthful as the tartrate baking powder, in fact the calcium and phosphorus in the calcium acid phosphate aid in building bones and teeth."¹

Advertising:
Space will not permit us to give the data concerning advertising.

Conclusions:
1. Royal Baking powder is most highly advertised.

¹ McCray, Doris W., A Housewife Looks at the Committee on Foods. Hygeia; Vol 12, pp. 330-331. (Not a direct quotation.)
2. Most of the advertisements were misleading.

3. Advertising does not serve as a criterion for intelligent buying.

4. Sixty-five percent of the consumers, who answered the questionnaire, used the two baking powders which were most highly advertised, Royal and Calumet.

In conclusion the pupils were asked the following question:

In your opinion what is the best baking powder which we have studied? State your reasons.

The student could choose any baking powder he preferred but his reasons for choosing it were supposed to be in harmony with data collected in the experiment, or with other authoritative data.