For mother & father
From Jack with Love,

A PRELIMINARY INVESTIGATION INTO THE PROCESS THROUGH WHICH ADOLESCENTS ACQUIRE SCIENTIFIC UNDERSTANDING

A. J. WHITEHEAD

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CONTENTS

ABSTRACT

This study presents the case that a shift is needed in the type and situation of educational research in this country if pragmatic knowledge of educative processes within schools is to be discovered.

In Chapter One the importance of experimentation in normal science follows a description of the rational, empirical and pragmatic philosophical approaches to knowledge and criteria to distinguish educative processes. It is then suggested that the methodologies of the cognitive theorists and experimentalists, illustrated by the work of J. Piaget and the principles of psychological testing, statistical inference and experimental design, should be combined in the scientific analysis of educative processes.

In Chapter Two the importance of concepts in the transmission of valued knowledge is illustrated by experiments on the effects of maturation and experience on concept development. Research designed to isolate causal variables in the transmission process is described and a study suggested for teachers who wish to increase the effectiveness of the transmission of valued knowledge. This involves the taxonomies of Bloom and Piaget being used together, to give content and construct validity to psychological tests.

Research to test the feasibility of a scientific investigation into the transmission of valued knowledge within schools is given in Chapter Three. This involves the use of a pre-test post-test with control group design and a standardized interview to gather the data. The data is processed using the analysis of covariance, and hypotheses are tested to detect if changes in consciousness can be ascribed to experiences arranged for the pupils. In conclusion it is suggested that teachers become educational researchers to improve the effectiveness of the transmission of valued knowledge through discovering pragmatic knowledge of educative processes within schools.

CHAPTER ONE

THE SCIENTIFIC ANALYSIS OF EDUCATIVE PROCESSES

Individuals in Britain experience eleven years compulsory schooling from a life expectancy of about 70 years[1]. This denial of freedom may be justified on the grounds that it is in the individuals interests to become educated. If a teacher is seriously concerned to prove that the experiences he arranges for his pupils are in fact educative he will need knowledge of educative processes. To clarify what is meant by knowledge of educative processes, criteria to distinguish processes as educative and the rational, empirical and pragmatic philosophical approaches to knowledge are described below.

Educative processes may be distinguished as involving the transmission of something worth while to those who are committed to it, some degree of cognitive perspective which is not inert and certain procedures of transmission are ruled out on the grounds that they lack wittingness on the part of the pupil[2]. When a process has been distinguished as likely to be educative the researcher has the problem of discovering knowledge of the process.

The concept of knowledge has several interpretations and the pragmatic approach is selected as more appropriate to solving the problems posed than the rational or empirical for the following reasons.

The rationalist[3] accepts mathematics for his model as the truths are general and necessary and may be established by deductive chains linking them with self evident basic truths. The empiricist accepts natural science as the model where natural phenomena are revealed by experience and not disclosed by intuition nor are their inter-relationships derivable from self evident axioms. The pragmatist stresses the experimental character of empirical science putting great emphasis upon the active phases of experimentation. I am using the idea of experimentation[4] not in the derogative sense used in many institutions meaning to treat children as guinea pigs for any innovation that comes along but treating the experiment as the only means of settling disputes regarding educational practice, as the only way of verifying educational improvements and as the only way of establishing a cumulative tradition in which improvements can be introduced without the faddish discard of old wisdom in favour of inferior novelties.

To solve the problems of proving that experiences are educative and discovering conditions which optimise the effective transmission of worthwhile knowledge one must learn something significant[3] about the world. That is one must do more than operate logically upon basic truths that appear to us self evident and we must go beyond reasonable generalisation of observed phenomenal patterns in our past experience. For these reasons and the fact that experimentation involves the active transformation of the environment in a manner dictated by leading ideas put forward in response to problems and directed toward the resolution of those problems, the pragmatist is considered most likely to discover a solution to the problems above. This choice must ultimately be decided as all questions of scientific theory are settled by finding out what theory best fits the knowledge discovered by experimental research[5].

How this knowledge may be discovered may be understood by considering what is meant by normal science and the methodologies of two major theoretical orientations in psychology, the cognitive theorists and experimentalists. A case will be presented later to show that the two methodolgies must necessarily be combined in the scientific analysis of educative processes.

Normal science[6] means research firmly based upon one or more past scientific achievements. This fact-gathering research makes a claim to empirical knowledge partly because it involves discovery through processes of controlled inference. The facts gathered may be classified as those which past achievements have shown to be particularly revealing of the nature of things, facts concerned with the direct comparison with prediction from theory and those which attempt to articulate theory. Theory[7] means in all empirical sciences the empirical formulation of determinate relations between a set of variables in terms of which a fairly extensive class of empirically ascertainable regularities can be explained.

The pragmatic theory of knowledge involves the mind as actively solving problems and stresses experimentation as part of the validating process[3]. The two methodologies concerned with the mind as actively solving problems and experimentation, are connected with the cognitive theorists and experimentalists respectively.

Cognitive theorists[8] are concerned with the developmental changes that occur in thinking and concept formation within the human organism, whilst the experimentalists have attempted to develop a science of cognitive ability based solely upon quantifiable behaviour. The latter have used standardized objective tests, developed sophisticated experimental designs and statistical analyses but failed to give unequivocal answers to the questions to which they were directed.

It is hoped to show later that these two methodologies must necessarily be combined in the scientific analysis of educative processes after the methods and finding of J. Piaget[9] are contrasted with the principles of psychological testing and statistical inference used in an experimental study into reading standards[10].

The discoveries of the cognitive theorists led by J. Piaget may support the claim that they have offered a unified comprehensive theory of mental development in the normal child[8]. Their methodology emphasizes observation, questioning and verbalisation of children in a naturalistic setting. A brief description of some important ideas of Piaget on the development of scientific thinking including those of schema and operation, precede some data, the stages and the classification of the logical operations at the stage of formal thought.

A schema[11] is a cognitive structure which has reference to a class of similar action sequences, these sequences of necessity being strong-bounded totalities in which the constituent behavioural elements are tightly interrelated. Concepts, described later, refer to cognitive structures not necessarily linked to actions, whilst schemas refer to the motor equivalent of a system of relations and classes. When cognitive actions are arranged into close-knit totalities, with definite strong structures they are called operations.

Piaget[9] classifies scientific thinking into three stages with sub-stages within each stage. In stage 1 although children demonstrate by their behaviour that they know how to act in the experimental situation sometimes successfully, they never internalize their actions as operations, even as concrete operations. By contrete operations he means actions which are integrated with other actions to form general reversible systems. The concrete operations distinguish stage 2. Reasoning is through class inclusion operations which allow the systematic distinction between 'ALL' or 'SOME' by means of the reversible addition $A + A' = B$, $B - A' = A$, which implies A is less than B. As a result of this operation the pupils become sensitive to contradiction and by co-ordinating two classes perceived as distinct can formulate a double entry table which allows relational operations. The pupil's logical apparatus can be viewed as composed of concrete class and relational operations. In contrast propositional operations which distinguish stage 3 from stage 1 and 2 consist in combining various empirical associations on which multiplicative classes are based in all possible ways. This type of thinking is believed to give rise to both the deductive capacity for demonstrative reasoning and the experimental capacity for the isolation of the relevant variables as each one may influence the end result.

The data, stages and classification which follow illustrate the method and some findings of Piaget and Inhelder[9]. The subject's task was to predict the stopping points while varying the size and weight of the balls and to explain the observed movement. The researchers took the assertions and tried to reduce them to logical formulae to see in which cases the subjects reasoned through arrangements of classes and relationships and in which cases they used propositional operations. The assertions have been separated from the stages and sub-stages which Piaget believes characterise the assertions as an example of how difficult it is to decide using linguisitic criteria into which stages the assertions should be placed as in many cases language remains implicit and the subject does not disentangle the details of his inference.

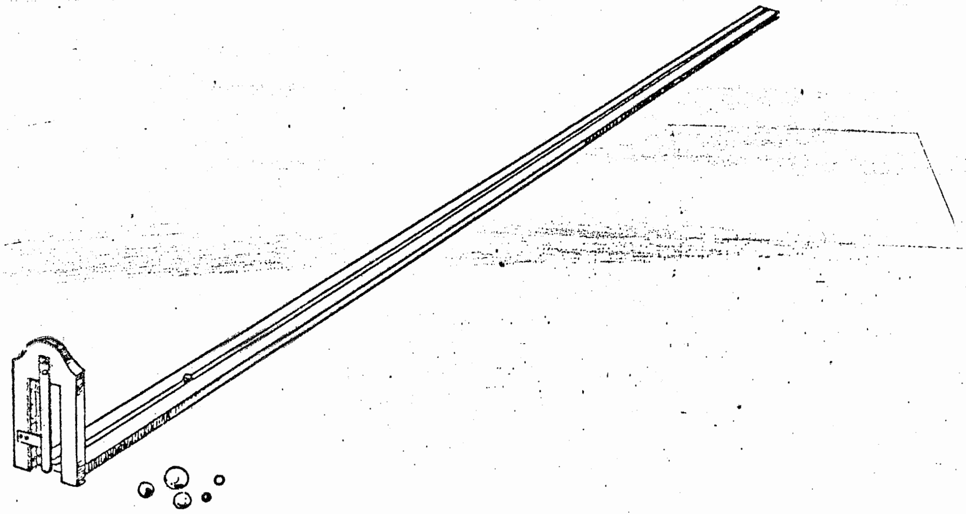


FIG. 7. Conservation of motion in a horizontal plane is demonstrated with a spring device which launches balls of varying sizes. These roll on a horizontal plane, and the subjects are asked to predict their stopping points.

RA (5 ; 4) tries to prolong or to stop the motion of the ball by framing it with his hands, which are placed parallel to it without touching. Sometimes the small and sometimes the large balls are supposed to go the furthest, the first because they are light and the second because they are heavy, but when a heavy one does not go far, it is *"because it's too heavy."*

BREI (6 ; 4): "Will they all go the same distance?"—*"No, there are some that will go further."*—"Which ones?"—*"That one"* [small wooden ball].—"Why?"—*"Because it's smaller."*—"Are there others which will go further?"—*"That one* [also a small wooden ball], *because it's smaller, and that one"* [large, copper].—"Why that one?"—*"Because it's bigger, and that one* [large, aluminum] *because it's big."* We ask the child to show where these four balls will stop and he answers: *"There* [7–8 units for the small wooden ball], *because it's smaller. That one* [large, aluminum] *there"* [13–14]. The small aluminum ball is also placed at 13–14 as is the small copper one; the large wooden ball at 5–6 *"because it's bigger, and that one there* [large, aluminum, at 19–20] *because it's big. This one here* [small wooden, at 24] *because it's smaller."* It is evident that the small ones are expected to go near or far [from 7–8 to 24] because they are small and the large ones near or far [from 5–6 to 19–20] because they are large. Next we ask for explanations, which we find similar but with a certain note of finality about them: *"It didn't get very far because it didn't have a flag."*

MEY (6 ; 8). The little wooden ball *"won't go very far because it's small."*—"And that one?" [large wooden ball]—*"It can't go very far because it's big."* Then: *"The two big ones will go less far because they're big. . . . The three little ones won't go as far as the big ones."*

PIR (7 ; 6): *"Some of them will go further than others."*—"Why?"—*"This one will go further because it is big and that one less far because it is small* [the first one is put in motion]. *It's less far than I thought."*—"Why?"—*"Because it's heavy."*

NIC (8 ; 0): *"The big one will go further because the little ones have more weight."* And *"that one won't go as far because it's big, heavy, and made of iron."*

HAL (8 ; 3): *"The big ones won't go as far because the little ones are lighter."* When a ball comes to rest close to the starting point: *"It's because it is heavier than I thought"* and, comparing a small copper ball to a large aluminum one, *"They go to the same place because they have the same weight."*

HOR (8 ; 6): *"This one* [large, aluminum] *will go further because it is heavy"* [force itself is tied to the weight]. She rolls the copper ball. *"It doesn't go as far because it is small."*—"And the other?"—*"I didn't push it hard enough."* Next the large wooden ball: *"It will go all the way to the bottom because it's light."*

JAD (10 years), referring to a zone of dispersion of about 20 cm., says of one ball, *"It is too heavy to go any further"* [than the extreme point] but at the same time *"it is too light"* to come to rest before the zone.

MAL (12 ; 3): "For a ball to go far?"—*"You have to pull the trigger* [spring] *hard"* [experiment]. "So, why didn't it go further?"—*"Yes, but it's a bad stretch* [plane insufficiently smooth]; *it won't go so far."*

CHAP (13 ; 3) predicts that the large ones will go further because they are heavier. After the experiment, he reverses his explanation.—"Why do the light ones go further?"—*"It depends on whether there is wind."* —"What?"—*"It's the wind* [= air] *that stops them from going on. When there isn't any wind, the light ones go far because nothing stops them."*—"And the heavy ones?"—*"I don't know."*

MET (13 ; 3): *"The air keeps it back and it doesn't go as far."*

DEV (14 ; 6) from the first experiment [large wooden ball]: *"It stopped because the air resists."*—"And this one?" [a small wooden ball, prediction].—*"It's about the same, but the ball is smaller: there is less resistance from the air and it will go further."*—"Is it the same for all of the balls?"—*"No, the bigger they are, the stronger the air resistance."* —"And for the small, heavy one?"—*"A heavier ball takes off less easily, but goes further because it has force in itself"* [weight = force!].—[Experiment] "So?"—*"That comes from the surface and the friction. The resistance varies with the substance the balls are made of: the wood is rougher, it scrapes more; the metal balls are smooth and will scrape less."*—[Experiment: small aluminum and large wood.]—*"Air resistance is proportional to size and weight* [!]."—"And if you compare this large aluminum ball with the small brass one?"—*"Oh! No, they take off with the same force. Only air resistance and friction come into play. . . . This ball* [brass] *is heavier and there will be more friction."* Conclusion: *"And if there were no air resistance, the ball would continue to roll."*

RAS (14 ; 4) *"Theoretically it should go to the end, but it's completely illogical"* [he means by illogical that which is contrary to the facts of direct experience]. Comparing a small and a large ball, he says again *"The friction is less for the little one. Air resistance also plays a role Theoretically, you would have to move it in a vacuum."*

DESB (14 ; 9): *"If you send them off with a push of the same strength it* [resting point] *depends on weight, friction, and volume."* Next, he doubts that volume plays any role, but in comparing a small and large ball, he says: *"The small one will go better because it has less friction, less air resistance."*—"That's all?"—*"If it's truly horizontal."*

Stage I. Absence of the Operations Necessary for an Objective Account of the Experiment and the Use of Contradictory Explanations

he very young subjects react to this experiment as they react to ie problem of floating bodies (Chap. 2)—*i.e.*, with a group of recausal predictions and explanations possessing certain reguirities but mutually contradictory: the light balls will go further ecause they are easier to set in motion and the large ones because ey are stronger; or there is no motion without force (the force esiding in the moving body or the force of the mover) and the otion stops of itself by extinction of the force imparted by the itial push, by fatigue, or by a tendency to rest.

The contradictions among the predictions bear witness to the osence of any law in the child's mind. His explanations do not chieve a greater coherence but relate all types of motion to a sort animated force.

Substage II-A. Attempts to Eliminate Contradictions and Corrections after the Experiment

lthough the conservation of motion may not always be seen (the otion is regarded as being due to a *force* in the Aristotelian nse, and the cessation of movement is spontaneous) and alough the predictions are based on variable factors (false or orrect), henceforth there is a certain internal consistency in the sertions as well as in the utilization of experimental results:

But the difficulty with an explanation in terms of force, such as sed at this level, is still that of reconciling the force with which he object is launched with the force of the moving body and nder conditions when the latter is heavy and when it is light.

In spite of the effort to eliminate them, a residue of contradicons is left from the fact that the heavy balls have a greater force hen in motion but are less easily set in motion, whereas the light ies have less force but are more easily launched.

Substage II-B. The Beginning of the Reversal of the Problem in the Direction of the Causes of Slowing Down

ie explanations used at this level are not different from the preding ones, in spite of the increasing but fruitless effort to unify e factors. However, since the child is increasingly sensitive to ance variation in the results, he exhibits a tendency to reverse e problem and to explain the causes of the slowing down rather an the cause of motion. He is not aware of this tendency. More rticularly, little by little weight ceases to be perceived as a use of motion and comes to be thought of as the (indirect) cause the balls' coming to rest. Moreover, to the extent that subjects nderstand that the variability of the stopping points is due to e factors of volume, weight, and force of launching, they are ore likely to think that weight and volume have a braking effect d even less likely to maintain that light weight and small size e causes of the prolongation of motion. These two kinds of sertions seem to be equivalent; the following will show that this not true in the least:

This kind of assertion shows clearly that the subject tends to invert the problem of motion. But he is that much less likely to suspect that his explanations remain the same as at substage II-A. In particular, he thinks of the air as promoting the motion by current backlash (ἀντιπερίστασις) rather than as an obstacle.

§ Substage III-A. Explicit Reversal of the Problem of Motion During the Experiment

The great difference between this level and the preceding ones is that from this point on the objective of the explanation is reversed; the problem is no longer to understand why the ball advances but what blocks its movement at a given moment.

As we have just seen, this reversal begins in substage II-B, but unconsciously. In contrast, although at first the III-B subjects are preoccupied in their predictions with motion, the experiment immediately leads them to focus their attention on the causes of the balls' slowing down or stopping. Thus, for these subjects the cessation of motion is no longer a positive state, the repose or aim of movement; instead, it becomes a negative state which must be explained by the intervention of new factors working in opposition to the positive state of motion.

Thus, starting with substage III-A, subjects touch on two causes of the cessation of motion: friction (terrain) and air resistance.

Without doubt the progress involved in reversing the explanation is due to the need to unify nascent formal thought. Since neither weight nor volume are causes of motion and (in contrast to explanations based on this conception) the ball goes further in proportion as it is both small and light, it follows that there is no simple cause for the continuation of motion. But it is more difficult to acknowledge multiple causes for motion itself (which may be considered the prototype of any simple phenomenon) than for the factors relating to the cessation of motion. However, even here the subject begins by looking for a unified explanation. He does so in spite of having seen the spread in results and chance fluctuations, which themselves were one of the reasons for his reversal of the question. That is why he does not succeed at first in this new line of attack. Time after time he fails to determine all the relevant variables simultaneously. Thus, CHAP discovers the factor of air resistance but fails to think of the friction for the heavy balls. MAL does the opposite, etc.

§ Substage III-B. Conservation of Motion

Finally, substage III-B leads to the fundamental explanation which results from the reversal of the positions taken at substage III-A: the conservation of motion by inertia. It should be said that all of the subjects do not solve the problem. Naturally, culture plays its diffuse role here. (Society had to wait for Galileo and Descartes with the "intellectual mutation," as A. Koyré called it, which resulted from their discovery.) But for certain subjects the rediscovery of the principle of inertia seems quite spontaneous, whereas for others there is, at least, a personal reconstruction of what they had learned:

The protocols show that the reasoning which leads to the con-rvation of motion is extremely simple and is furnished in the ost explicit form by DEV. The first stage consists of establishing e causes of the balls' slowing down or stopping. If we let p be e statement concerning slowing down or stopping, and let r, s, t, etc., be statements of friction or air resistance, irregu-rities of the track, of an eventual lack of (perfect) horizontality, c., then:

$$p \supset (q \vee r \vee s \vee t \vee \ldots). \qquad (1)$$

Inversely, at the second stage the subject asks himself what ould be the result of the negation of all of these factors, this gation implying a corresponding negation of statement p, that slowing down. This is equivalent to the assertion of the con-uation of motion:

$$\bar{q}.\bar{r}.\bar{s}.\bar{t} \ldots \supset \bar{p}. \qquad (2)$$

It is interesting to compare this form of conservation, which is ecific to formal thinking, with numerous concrete forms of con-rvation (wholes, lengths, weights, etc.; conservation of volume d surface area imply formal thought only because of the pro-rtions). In both cases, conservation is achieved because of the le played by reversible operations (reversible by inversion or gation). When a modification arises as the result of the experi-ental actions, they allow a correction to be made for it by a ansformation in the opposite direction (and thus a return to the ll transformation). But in the case of concrete thinking this verse transformation, even if it occurs only mentally, is of the me order as experimental modifications which alter the system d could in fact be carried out by the subject. For example, e transformation of a stretched-out section of modeling clay can annulled by pushing it into a more compact mass, for what the ject has gained in length it has lost in thickness. Thus it is pos-ble to restore it by actions involving inverse modifications.

In contrast, in the case of the conservation of motion, opera-onal reversibility occurs at the mental level only and does not rrespond to any transformation which can be realized in full the subject even in a laboratory situation. Even if one could iminate all the causes of slowing down (though it is in fact npossible), one would still have to make use of an infinite amount space and time to verify the principle of inertia completely. evertheless, the substage III-B subject manages to discard entally the causes of stopping by thinking in terms of what is eoretically possible (but which cannot occur in fact) or, in her words, in terms of purely hypothetico-deductive implica-ons.

Having done this, once more a reversible operation—(1) and (2)—suffices; here it is the counterposition (equivalence of $p \supset q$ and $\bar{q} \supset \bar{p}$), but in this case it rests on the double negation of ($p \vee q \vee r \vee \ldots$) resulting in ($\bar{p}.\bar{q}.\bar{r}. \ldots$) (thus of p or q or $r \ldots$ resulting in neither p nor q nor $r \ldots$) and of p result-ing in $\bar{p}$.

One may, if one wishes, say that this reversibility comes back to the famous principle *tollitur causa, tollit effectus,* but on the one hand in order to eliminate the causes in the particular case the subject must think in terms of what is theoretically possible; on the other hand, since these causes cannot be eliminated in fact, the operation amounts to inverting an implication to give its con-verse by changing signs. Thus, the subject is proceeding on the basis of pure implications and no longer on the basis of trans-formations which can actually be effected.

We now see both the similarity and the differences between the several forms of conservation: all are based on a group prin-ciple (which is qualitative or logical before becoming quantita-tive or metrical), but conservation may be achieved either by concrete operations of classes and relations [4] (or at an even earlier stage by the integration of parts into a whole object) or, as at the formal stage, by the use of interpropositional operations alone.

PIAGET'S BINARY PROPOSITIONAL CLASSIFICATION FOR THE STAGE OF FORMAL OPERATIONS

		p	$\bar{p}$	Symbolic Representation	Operation	Propositions to Indicate Relationship Between Two Variables p and q
(1)	q	+	+	$pq \vee p\bar{q} \vee \bar{p}q$	Disjunction	Either p is true or q is true or both are true
	$\bar{q}$	+	0			
(2)	q	0	0	$\bar{p}\ \bar{q}$	Inverse of (1) Conjunctive negation	It is neither
	$\bar{q}$	0	+			
(3)	q	+	0	$p\ q$	Conjunction	Both are effective
	$\bar{q}$	0	0			
(4)	q	0	+	$\bar{p}q \vee p\bar{q} \vee \bar{p}\bar{q}$	Inverse of (3) Incompatibility	Either p is false or q is false or both are false
	$\bar{q}$	+	+			
(5)	q	+	+	$pq \vee \bar{p}q \vee \bar{p}\bar{q}$	Implication	p implies q
	$\bar{q}$	0	+			
(6)	q	0	0	$p\bar{q}$	Inverse Implication	p does not imply q
	$\bar{q}$	+	0			
(7)	q	+	0	$pq \vee p\bar{q} \vee \bar{p}\bar{q}$	Converse Implication	q implies p
	$\bar{q}$	+	+			
(8)	q	0	+	$\bar{p}q$	Inverse of 7	q does not imply p
	$\bar{q}$	0	0			
(9)	q	+	0	$pq \vee \bar{p}\bar{q}$	Equivalence	p is equivalent to q
	$\bar{q}$	0	+			
(10)	q	0	+	$p\bar{q} \vee \bar{p}q$	Inverse of 9 Reciprocal Exclusion	When p is true q is false
	$\bar{q}$	+	0			
(11)	q	+	0	$pq \vee p\bar{q} = p$	Independence	p is independent of q
	$\bar{q}$	+	0			
(12)	q	0	+	$\bar{p}q \vee \bar{p}\bar{q}$	Inverse of 11	p is not true
	$\bar{q}$	0	+			
(13)	q	+	+	$pq \vee \bar{p}q = q$	Independence	q is independent of p
	$\bar{q}$	0	0			
(14)	q	0	0	$p\bar{q} \vee \bar{p}\bar{q}$	Inverse of 13	q is not true
	$\bar{q}$	+	+			
(15)	q	+	+	$pq \vee p\bar{q} \vee \bar{p}q \vee \bar{p}\bar{q}$	Tautology	p is independent of q
	$\bar{q}$	+	+			
(16)	q	0	0	$pq \vee p\bar{q} \vee \bar{p}q \vee \bar{p}\bar{q}$	Negation	None of these cases occur
	$\bar{q}$	0	0			

The above methodology and discoveries of the cognitive theorists may be contrasted with the methodology of the experimentalists by considering the principles of psychological testing, statistical inference and experimental design used in a study into reading standards.

A psychological test is essentially a standardized and objective measure of a sample of behaviour[12]. Standardization implies uniformity of procedure in administering and scoring the test. The objective evaluation involves primarily the determination of the reliability and validity of the test in a specified situation. The reliability of a test can be measured using the consistency of test scores between one administration of a test and the next. One method of determining the reliability uses the internal consistency of the test by which each item is considered as assisting toward the final rank order to a degree dependent on its own variance. A high reliability in the measuring instrument is important when one wishes to attribute changes in a dependent variable to another variable independent of the measuring instrument. A test may, however, be reliable but fail to measure what it is required to measure. This property of a test is its validity, and predictive, concurrent, content and construct validity have been distinguished[13]. Predictive validity asks if test scores predict future performance and its principal use is for selection and classification decisions. Concurrent validity asks if test scores permit an estimate of a present performance and is used on tests intended as substitutes for less convenient procedures. Content validity asks if the test gives a fair measure of performance on some important set of tasks and is used for achievement tests. Construct validity asks how the scores of tests can be explained psychologically and this is used for descriptions or scientific research. The importance of content and construct validity for psychological tests used to investigate educative processes will be discussed in Chapter Two when it will be suggested that Bloom's[14] taxonomy applied to the conceptual development of a subject and Piaget's[9] classification of psychological development should be applied together in research designed to isolate causal variables in educative processes.

The data gathered from psychological tests is often processed using statistical analysis from which inferences are made about the significance of the data. Statistical analysis[15] involves making assumptions, obtaining a sampling distribution, selecting a significance level and computing the test statistic. Inferences are often drawn about the empirical data from the results of these tests.

The basic assumption or model which is accepted when carrying out one important statistical analysis is that any pupil's score can be regarded as made up of three parts, a part common to all scores, a part characteristic of the particular method and a part characteristic of the particular pupils, all of which are assumed to be independent and additive. From the assumptions a sampling distribution may be obtained by purely mathematical reasoning. From this distribution the exact probabilities that certain outcomes will occur if the assumptions are actually true can be determined. The probability of obtaining the best statisitic, which is obtained from the data, is usually determined and if there is a one in a hundred chance of obtaining this result by chance alone it may be decided that factors other than chance are operating. It is important to realise that no causal connection is necessarily implied in this analysis. The relationships discovered are in terms of mathematical functions and it is the experimenter who infers causal relationships from the processed data.

In experiments designed to isolate and quantify causal variables, it is usual to measure the effect of an independent variable on a dependent variable. A true experiment[4] is designed with a control group where the constancy of the independent variables allows the unambiguous assignment of differences observed in the dependent variable, to an independent variable in the treatment group, within the limits of experimental error. The equivalence of the groups at the beginning of an experiment should be ensured by the random allocation of pupils, methods, teachers, schools etc, to their groups. This may be a less than perfect way of ensuring equivalence but it is the best we have.

The practical application of the methods outlined above is illustrated by the following recent research whose aim was to measure reading standards and to compare these standards with the results from previous surveys. The complexity of the experimental design and sampling procedure may be inferred from the following extract.

"Now we had a sample of children derived by second stage sampling fraction from a sample of schools derived by first stage sampling fraction from a stratified population of the schools in the maintained and direct grant sector of our educational system. By working backwards from the children's scores through the second stage sampling fraction (in this direction often called weightings), we can make estimates about achievements of children in schools of different type and size. Further, by working backwards from this level through the first stage sampling fraction we can make estimates of national levels of reading comprehension of children in the country's schools"[10].

The Watts Vernon and National Survey Form 6, (two silent reading comprehension tests) were used to assess reading standards. The Watts Vernon test is 23 years old with a reliability of .90. There are 23 items and it takes 10 minutes to administer. The NS 6 is 16 years old with a reliability of .94. It consists of 60 items and takes 20 minutes to administer. The items of both tests consist of a sentence with one word missing and the pupil is requested to pick the one word out of a choice of five that makes the sentence sensible.

From the evidence collected it was suggested that a drop in reading standards had occurred between 1964 to 1971. There was some difficulty in interpreting the results as over a quarter of the schools randomly allocated to testing groups did not take part in the experiment. It is also pointed out that much of the discussion about the results hinges on the appropriateness of the measures of reading comprehension and the author emphasizes that the tests were used not as a means of making judgements about individuals but to assess changes in standards of whole populations.

It is hoped that the methodologies and findings described above illustrate the difference between the methodologies of the cognitive theorists and experimentalists. By experimentalists I am simply referring to researchers who employ the principles of psychological testing, statistical inference and experimental design in their studies of educative processes. Unfortunately there has been no national study into scientific thinking using the experimentalists methodology to contrast with the findings of cognitive theorists, who stress the mind as actively solving problems. The elimination of the concept of mind from much contemporary psychology[5] is a matter of concern to this researcher who follows Burt's[16] opinion that the difficulties about consciousness arise out of talking about it as if it were a substance or attribute ratherthan as relation. For the scientist there should be no doubt that the problem of interaction of mind and matter is a real problem and not a pseudo problem arising out of confusion in the use of words. Ultimately, however, as stated previously, this must be settled by experimental research. It will now be argued that scientific research into educative processes implies the use of both the above methodologies. Educative processes within schools involve the transmission of valued knowledge to children and adolescents. Teachers attempt to arrange experiences for the child which enable valued knowledge to be constructed by the child. Researchers need to assess these meanings given to experiences by the child if they are to prove the experiences are educative and wish to optimise the effectiveness of the transmission process. The cognitive theorists emphasize the meanings given by the child to his experiences and their findings could be used to give construct validity to the tests. A method of giving content and construct validity to the tests is described in Chapter Two.

To show that the independent variables, that is, the experiences arranged by the teacher, affect the dependent variables, i.e. the meanings constructed by the child, one needs the methodology of the experimentalists. The methodology of the cognitive theorists is needed to detect and measure changes in the state of consciousness whilst the methodology of the experimentalists can ascribe changes in consciousness to independent variables within known limits of error.

Both methodologies are thus needed in the scientific analysis of educative processes.

The following chapter considers research into the transmission of valued knowledge and a study is suggested which would combine both methodologies in the analysis of transmission processes.

CHAPTER TWO

TRANSMITTING VALUED KNOWLEDGE

In schools knowledge is often transmitted through subjects which may be grouped within moral, historical, mathematical, scientific and aesthetic forms of knowledge distinguishable by their frameworks, concepts and methods of validation[17]. The fact that so little is known about the formation of relational concepts which are the bases of scientific thinking has recently puzzled the Schools Council[18]. Present knowledge of how scientific concepts develop is illustrated by the experiments which follow the brief analysis of what is meant by a concept.

Understanding what it is to have a concept covers both the experience of grasping a principle and the ability to discriminate and use words correctly[19]. This puts emphasis on philosophy as an activity which must be learnt and understood. It is not considered as the explication of the principles through language but rather the experiencing of them in action in language. A concept[20] enablesa person to relate previous learning to current situations arising within the persons present experience and they are formed[21] as a result of the perception of the common qualities or aspects of related objects, materials or phenomena. An example may help to distinguish between a concept and the connected notion of a percept. The harvest moon near the horizon appears much larger than the moon seen high in the sky. We perceive the difference but the concept of invariance enables us to judge the size of objects and the moon is not thought to change size just because it appears to do so. The method of analysing related concepts often helps to clarify the concepts with which one is primarily concerned. When one is clear about what is meant by a concept it is often useful to detect the state of formation of concepts and to investigate methods which might accelerate their development. Several of the experiments below illustrate these problems.

The state of formation of fundamental concepts of matter, weight, length, area, volume, space, time, velocity, physical causality and logical thinking necessary to understand the scientific nature of things has been detected by conservation experiments[11]. In these experiments the form of a liquid or object is changed or displaced and questions asked to see if the child has conserved the quantity.

Piaget attaches primary importance to conservation and has described it as a necessary condition for all rational activity. The following studies were undertaken to detect the effects of maturation and experience on the development of scientific concepts.

Deutsche[22] studied 700 children between the ages of 8 and 16. They were asked questions based upon those used by Piaget to investigate causal relations. She believed that the children gave more materialistic explanations as they became older because of tuitional or experiential factors relating to schooling rather than maturation.

In King's[23] study of the scientific concepts of children between the ages of 5 - 12 he found that questions concerned with volume and weight conservation did not show an increase in performance with age whilst for some questions such as 'Is the sun alive?' there was a steady increase of performance with age.

Piaget's conclusion that a child conserves because he is able to carry out certain logical operations and is convinced of the logical necessity of conservation was not confirmed by Lovell and Ogilvie[24] who found that the child who had conserved the weight of a lump of plasticine during change of shape could not necessarily conserve the weight of a piece of butter.

The conclusions of these studies that stages do not exist and the implication that the power of experience in developing the mind is limitless cannot be taken as conclusive evidence for the effect of experience on concept development as training histories were not controlled[20]. Conclusive evidence of the effects of experience on concept development may be obtained by the use of true experimental designs in the analysis of educative processes. Some effects of experience on the development of concepts have been demonstrated in the following studies.

Suchman[25] confronted a child with a problem, encouraged him to ask any questions he wanted and gave him the answers to these questions but no other information. After these sessions the teacher and child discussed the way in which the questions asked attacked the problem and the child led to recognize the way in which the approach could have been more successful. Children of 10 years of age were able to approach problems logically to formulate generalizations and display thinking characteristic of Piaget's stage of formal operations not normally achieved until adolescence.

Formation of the concept of weight was found to be best helped by the introduction to units of weight followed by exercise in the measurement of weight before embarking on the comparison and judgement of weights of various objects[26].

Smedslund[27] tackled the problem of the permanence of concepts developed by training in particular experiences. His research led to the conclusion that the trained conservers had learnt conservation but had not arrived at a concept of conservation as a logical necessity. The idea that true concept formation required a reorganisation of ways of thinking prompted him to try to induce conservation by cognitive conflict. Two competing approaches to solving the problem forced the child to consider which should be followed, and this led to the cognitive reorganisation needed for a logically necessary concept to be formed. He found the conflict approach the most successful of all the methods of inducing conservation which he had tried.

There has been some success in inducing conservation by training in logical operations[20]. Results have supported the idea that experience with actions which demonstrate reversibility and make conscious the temporary nature of reversible changes can lead to the development of number conservation and very probably conservation of other quantities as well. Analysis of how a child becomes able to conserve has led to the conclusion that conservation is possible only when the mental operations of multiple classification, multiple relationality and reversibility are present as the cognitive structures basic to adequate conservation performance necessary for scientific thinking.

Piaget's illustration that a child could solve 2 times 2 and 3 times 3 matrix problems at 8 or 9 at the operational level using the system of double entry classification provided the starting point for one of Mealing's[28] experiments in his study of problem solving in science at the secondary school stage. In one experiment the apparatus consisted of 3 red blocks and 2 of blue from deal and 1 red and 2 blue blocks from a denser hard wood and a balance.

The problem was to find out if there were more heavy blocks than red blocks. This tested the ability to see the relevance of a double entry system of classification to the solution of the problem and to mentally arrange raw data into a matrix in order to solve the problem. It was found that below a mental age of 13.8 years no one could solve the problem. This study of problem solving did not attempt to explain how experiences could help the pupil to solve the problems. The responses were fitted into a classification and little about causal variables could be deduced from the study.

The technique used to assess the quality of adolescent thought by posing a problem and encouraging the adolescent to think through his solution aloud may be used to develop classifications or the responses fitted into an existing classification. In the study above Piaget's classification was used and in a similar study[29] on the extent to which some adolescents induce scientific principles from scientific experiments answers were fitted into Deutsche's classification of materialistic and non-materialistic explanations. One experiment consisted of two teapots one with a small hole in the lid and the other with an air-tight lid. The pupils had to talk through their explanations that the water would not pour out of the second teapot. There were several experiments involving pressure and density and in each case the response was fitted into Deutsche's classification from which little can be deduced in terms of causal variables.

The independent and dependent variables are the factors which are manipulated and measured. One problem is to show that a significant difference exists between a group which has received a treatment and a group which has received no treatment. Another problem is to ascribe the difference to the treatment. One of the studies[30] below investigates changes in the state of consciousness before and after treatments. This study has limited application to teachers of adolescents as it was limited to E.S.N. pupils, the concepts involved were fundamental ones on which a great deal of work has already been done and not the relational ones which concern most teachers in secondary schools.

51 children[30] aged 10 to 16 with I.Qs. between 50 to 77 who had failed to conserve on two or more conservation tasks involving number, substance, length, distance, area, weight and volume, were divided into 3 matched groups. A pre-test post-test with control group design was used. One group received instructions on conservation of a variety of attributes and the second group on conservation of area alone. The control group was given practice in reading. 30 of 34 instructed children consistently recognised, generalised and gave reasons for conservation on both post-tests. No control child improved in understanding of conservation by the time of the second post-test.

That only a few studies have been undertaken which attempt to isolate causal variables is highlighted by the claim of researchers at Leicester[31] that the following attempt to measure the effects of teaching style on attitudes and attainment in science is the first large scale evaluations study based on classroom observation to be carried out.

Teaching style is being measured using a Science Teaching Observation System developed by the team of researchers. The countrywide sample of 113 teachers being observed are teaching fourth year science courses. Each teacher will be observed on four occasions by one out of a team of 40 observers. An intensive study, using five teachers is planned to collect information on the reliability of the observation schedule. Over 9,000 pupils have been used to pre-test the cognitive tests in chemistry, physics and biology. Secondary hypotheses which the researchers hope to test are that for a given teaching style the effectiveness of that style is measured by the pupils attainment and attitude scores will vary according to the pupils ability and that for a given teaching style the effectiveness of that style will vary according to the science subject being taught.

In scientific thinking it is important to develop the abilities to register raw results, make classifications and note correspondences, isolate and quantify causal variables, eliminate contradictions and test hypotheses by experiment. Two types of research into scientific thinking may be distinguished above. In the first type the results are fitted into classifications or used to develop new classifications. In the second type the facts allow the isolation and quantification of causal variables and hypothesis testing. The suggested study below is given to illustrate how a teacher as educational researcher could discover knowledge of educative processes which may be useful in optimising the development of scientific thinking, through type 2 research. This is followed in Chapter Three by a study to test the feasibility of this type of research being carried out within the science department of a comprehensive school.

To discover knowledge which may be useful in improving the transmission of valued knowledge, the teacher as educational researcher has the problem of discovering what meanings are constructed by the child from the experiences he arranges. Two distinct problems immediately arise. What method could be used to detect these changes in the state of consciousness and how can they be attributed to known causes. The first problem may be solved by considering the logical and psychological aspects of teaching a subject[32]. The science teacher is attempting to transmit a subject which is a logically cohesive discipline, to a child whose psychological state is changing, perhaps as a result of the teaching. Tests could measure these changes in the child in terms both of the logical development of a subject and the psychological development of the child. That is the tests could have both content and construct validity. This could be ensured by experts in a form of knowledge designing items within Bloom's Taxonomy of Educational Objectives overleaf which would be nested within a classification such as Piaget's given in Chapter One. The results of this test could give an indication both of achievement within a subject and the pupils psychological state in terms of cognitive development.

Condensed Version of the Taxonomy of Educational Objectives[2]

Cognitive Domain

KNOWLEDGE

00 KNOWLEDGE

nowledge, as defined here, involves the recall of specifics and universals, e recall of methods and processes, or the recall of a pattern structure, setting. For measurement purposes, the recall situation involves little ore than bringing to mind the appropriate material. Although some teration of the material may be required, this is a relatively minor part the task. The knowledge objectives emphasize most the psychological rocesses of remembering. The process of relating is also involved in that knowledge test situation requires the organization and reorganization of problem such that it will furnish the appropriate signals and cues for the nformation and knowledge the individual possesses. To use an analogy, one thinks of the mind as a file, the problem in a knowledge test situation that of finding in the problem or task the appropriate signals, cues, and lues which will most effectively bring out whatever knowledge is filed or ored.

.10 KNOWLEDGE OF SPECIFICS

he recall of specific and isolable bits of information. The emphasis is on ymbols with concrete referents. This material, which is at a very low vel of abstraction, may be thought of as the elements from which more omplex and abstract forms of knowledge are built.

11 KNOWLEDGE OF TERMINOLOGY

nowledge of the referents for specific symbols (verbal and non-verbal). his may include knowledge of the most generally accepted symbol ferent, knowledge of the variety of symbols which may be used for a ngle referent, or knowledge of the referent most appropriate to a given e of a symbol.

To define technical terms by giving their attributes, properties, or lations.

Familiarity with a large number of words in their common range of eanings.

12 KNOWLEDGE OF SPECIFIC FACTS

nowledge of dates, events, persons, places, etc. This may include very ecise and specific information such as the specific date or exact magtude of a phenomenon. It may also include approximate or relative formation such as an approximate time period or the general order of agnitude of a phenomenon.

The recall of major facts about particular cultures.

The possession of a minimum knowledge about the organisms studied the laboratory.

Illustrative educational objectives selected from the literature.

20 KNOWLEDGE OF WAYS AND MEANS OF DEALING WITH SPECIFICS

owledge of the ways of organizing, studying, judging, and criticizing. is includes the methods of inquiry, the chronological sequences, and e standards of judgment within a field as well as the patterns of organizaon through which the areas of the fields themselves are determined and ternally organized. This knowledge is at an intermediate level of straction between specific knowledge on the one hand and knowledge universals on the other. It does not so much demand the activity of the udent in using the materials as it does a more passive awareness of their ture.

21 KNOWLEDGE OF CONVENTIONS

nowledge of characteristic ways of treating and presenting ideas and enomena. For purposes of communication and consistency, workers in field employ usages, styles, practices, and forms which best suit their rposes and/or which appear to suit best the phenomena with which they al. It should be recognized that although these forms and conventions e likely to be set up on arbitrary, accidental, or authoritative bases, ey are retained because of the general agreement or concurrence of dividuals concerned with the subject, phenomena, or problem.

Familiarity with the forms and conventions of the major types of orks, e.g. verse, plays, scientific papers, etc.

To make pupils conscious of correct form and usage in speech and iting.

1.22 KNOWLEDGE OF TRENDS AND SEQUENCES

Knowledge of the processes, directions, and movements of phenomena with respect to time.

* Understanding of the continuity and development of American culture as exemplified in American life.
* Knowledge of the basic trends underlying the development of public assistance programs.

1.23 KNOWLEDGE OF CLASSIFICATIONS AND CATEGORIES

Knowledge of the classes, sets, divisions, and arrangements which are regarded as fundamental for a given subject field, purpose, argument, or problem.

* To recognize the area encompassed by various kinds of problems or materials.
* Becoming familiar with a range of types of literature.

1.24 KNOWLEDGE OF CRITERIA

Knowledge of the criteria by which facts, principles, opinions, and conduct are tested or judged.

* Familiarity with criteria for judgment appropriate to the type of work and the purpose for which it is read.
* Knowledge of criteria for the evaluation of recreational activities.

1.25 KNOWLEDGE OF METHODOLOGY

Knowledge of the methods of inquiry, techniques, and procedures employed in a particular subject field as well as those employed in investigating particular problems and phenomena. The emphasis here is on the individual's knowledge of the method rather than his ability to use the method.

* Knowledge of scientific methods for evaluating health concepts.
* The student shall know the methods of attack relevant to the kinds of problems of concern to the social sciences.

1.30 KNOWLEDGE OF THE UNIVERSALS AND ABSTRACTIONS IN A FIELD

Knowledge of the major schemes and patterns by which phenomena and ideas are organized. These are the large structures, theories, and generalizations which dominate a subject field or which are quite generally used in studying phenomena or solving problems. These are at the highest levels of abstraction and complexity.

1.31 KNOWLEDGE OF PRINCIPLES AND GENERALIZATIONS

Knowledge of particular abstractions which summarize observations of phenomena. These are the abstractions which are of value in explaining, describing, predicting, or in determining the most appropriate and relevant action or direction to be taken.

* Knowledge of the important principles by which our experience with biological phenomena is summarized.
* The recall of major generalizations about particular cultures.

1.32 KNOWLEDGE OF THEORIES AND STRUCTURES

Knowledge of the *body* of principles and generalizations together with their interrelations which present a clear, rounded, and systematic view of a complex phenomenon, problem or field. These are the most abstract formulations, and they can be used to show the interrelation and organization of a great range of specifics.

* The recall of major theories about particular cultures.
* Knowledge of a relatively complete formulation of the theory of evolution.

bilities and skills refer to organized modes of operation and generalized chniques for dealing with materials and problems. The materials and oblems may be of such a nature that little or no specialized and tech-cal information is required. Such information as is required can be sumed to be part of the individual's general fund of knowledge. Other oblems may require specialized and technical information at a rather gh level such that specific knowledge and skill in dealing with the oblem and the materials are required. The abilities and skills objectives nphasize the mental processes of organizing and reorganizing material achieve a particular purpose. The materials may be given or remem-ered.

.00 COMPREHENSION

his represents the lowest level of understanding. It refers to a type of nderstanding or apprehension such that the individual knows what is eing communicated and can make use of the material or idea being ommunicated without necessarily relating it to other material or seeing s fullest implications.

.10 TRANSLATION

omprehension as evidenced by the care and accuracy with which the ommunication is paraphrased or rendered from one language or form of ommunication. Translation is judged on the basis of faithfulness and ccuracy, that is, on the extent to which the material in the original ommunication is preserved although the form of the communication has een altered.

The ability to understand non-literal statements (metaphor, symbolism, ony, exaggeration).

Skill in translating mathematical verbal material into symbolic state-ents and vice versa.

20 INTERPRETATION

he explanation or summarization of a communication. Whereas anslation involves an objective part-for-part rendering of a communica-on, interpretation involves a reordering, re-arrangement, or a new view f the material.

The ability to grasp the thought of the work as a whole at any desired vel of generality.

The ability to interpret various types of social data.

.30 EXTRAPOLATION

he extension of trends or tendencies beyond the given data to determine nplications, consequences, corollaries, effects, etc., which are in accord-nce with the conditions described in the original communication.

The ability to deal with the conclusions of a work in terms of the nmediate inference made from the explicit statements.

Skill in predicting continuation of trends.

00 APPLICATION

he use of abstractions in particular and concrete situations. The abstrac-ons may be in the form of general ideas, rules of procedures, or eneralized methods. The abstractions may also be technical principles, eas, and theories which must be remembered and applied.

Application to the phenomena discussed in one paper of the scientific rms or concepts used in other papers.

The ability to predict the probable effect of a change in a factor on a ological situation previously at equilibrium.

00 ANALYSIS

ne breakdown of a communication into its constituent elements or rts such that the relative hierarchy of ideas is made clear and/or the lations between the ideas expressed are made explicit. Such analyses e intended to clarify the communication, to indicate how the communica-on is organized, and the way in which it manages to convey its effects, well as its basis and arrangement.

10 ANALYSIS OF ELEMENTS

entification of the elements included in a communication.

The ability to recognize unstated assumptions.

Skill in distinguishing facts from hypotheses.

4.20 ANALYSES OF RELATIONSHIPS

The connections and interactions between elements and parts of a communication.

* Ability to check the consistency of hypotheses with given information and assumptions.
* Skill in comprehending the interrelationships among the ideas in a passage.

4.30 ANALYSIS OF ORGANIZATIONAL PRINCIPLES

The organization, systematic arrangement, and structure which hold the communication together. This includes the 'explicit' as well as 'implicit' structure. It includes the bases, necessary arrangement, and the mechanics which make the communication a unit.

* The ability to recognize form and pattern in literary or artistic works as a means of understanding their meaning.
* Ability to recognize the general techniques used in persuasive materials, such as advertising, propaganda, etc.

5.00 SYNTHESIS

The putting together of elements and parts so as to form a whole. This involves the process of working with pieces, parts, elements, etc., and arranging and combining them in such a way as to constitute a pattern or structure not clearly there before.

5.10 PRODUCTION OF A UNIQUE COMMUNICATION

The development of a communication in which the writer or speaker attempts to convey ideas, feelings, and/or experiences to others.

* Skill in writing, using an excellent organization of ideas and statements.
* Ability to tell a personal experience effectively.

5.20 PRODUCTION OF A PLAN OR PROPOSED SET OF OPERATIONS

The development of a plan of work or the proposal of a plan of operations. The plan should satisfy requirements of the task which may be given to the student or which he may develop for himself.

* Ability to propose ways of testing hypotheses.
* Ability to plan a unit of instruction for a particular teaching situation.

5.30 DERIVATION OF A SET OF ABSTRACT RELATIONS

The development of a set of abstract relations either to classify or explain particular data or phenomena, or the deduction of propositions and relations from a set of basic propositions or symbolic representations.

* Ability to formulate appropriate hypotheses based upon an analysis of factors involved, and to modify such hypotheses in the light of new factors and considerations.
* Ability to make mathematical discoveries and generalizations.

6.00 EVALUATION

Judgments about the value of material and methods for given purposes. Quantitative and qualitative judgments about the extent to which material and methods satisfy criteria. Use of a standard of appraisal. The criteria may be those determined by the student or those which are given to him.

6.10 JUDGMENTS IN TERMS OF INTERNAL EVIDENCE

Evaluation of the accuracy of a communication from such evidence as logical accuracy, consistency, and other internal criteria.

* Judging by internal standards, the ability to assess general probability of accuracy in reporting facts from the care given to exactness of statement, documentation, proof, etc.
* The ability to indicate logical fallacies in arguments.

6.20 JUDGMENTS IN TERMS OF EXTERNAL CRITERIA

Evaluation of material with reference to selected or remembered criteria.

*The comparison of major theories, generalizations, and facts about particular cultures.

* Judging by external standards, the ability to compare a work with the highest known standards in its field — especially with other works of recognized excellence.

The second problem above was to ascribe changes in the state of consciousness to known causes as unambiguously as possible. This may be solved if these tests were reliable and could be designed with content and construct validity as described above and true experimental designs described in Chapter Three were used. The random allocation of pupils to groups and the other controls mentioned could help in the detection of the effect of experiences arranged by the teacher on the meanings constructed by the pupil.

The feasibility of carrying out this research within schools with the aim of experimenting to optimise the effective transmission of valued knowledge has not been tested to my knowledge in this country. The following study tests the feasibility of carrying out this type of research within the science department of a comprehensive school.

CHAPTER THREE

THE FEASIBILITY OF INVESTIGATING THE TRANSMISSION OF VALUED KNOWLEDGE WITHIN A SCHOOL BY A TEACHER AS EDUCATIONAL RESEARCHER

1) THE EXPERIMENTAL GROUPS

180 pupils in the first year were grouped on the results of internal mathematics and english tests, by adding the results, rank ordering and dividing into three unequal bands. The 'B' bandwas chosen for study because the 54 pupils could be randomly allocated to three groups, which were taught by different teachers, the course content was the same for the treatment groups and a pre-test post-test control group design could be used.

2) THE EXPERIMENTAL DESIGN

There are three basic true experimental designs recommended in the methodological[38] literature which can be used to investigate educational processes. In the designs illustrated below O is an observation, X treatment and R refers to randomisation.

DESIGN 1 Pre-test Post-test with control group design

$$\begin{array}{llll} R & O_1 & X & O_2 \\ R & O_3 & & O_4 \end{array}$$

DESIGN 2 The Soloman Four Group Design

$$\begin{array}{llll} R & O_1 & X & O_2 \\ R & O_3 & & O_4 \\ R & & X & O_5 \\ R & & & O_6 \end{array}$$

This design had the advantage over designs 1 and 3 in that both the main effects of testing and the interaction of testing and X are determinable.

DESIGN 3 The post-test only control group design

$$\begin{array}{lll} R & X & O_1 \\ R & & O_2 \end{array}$$

This design controls for testing as main effect and interaction but does not measure them.

Design 2 was preferred to 1 and 3 for the reasons stated but it was impossible to randomly allocate pupils to 4 groups because of the internal organization of 3 teachers to 1 band of ability. Design 1 was chosen for the study as it was initially intended to study the interaction of the treatment at the pre-test ability level, which pre-test scores make possible. In retrospect, however, design 3 should have been used as no results were gathered on a pre-test ability level owing to the time available and the results of the present study were used to show the effects of certain treatments. This could have been done with design 3 which assured initial equivalence of groups by randomisation and would have avoided any reactivity of the pre-test with the treatment and control groups. The internal validity of the experiment rests upon the equivalence of the groups and several factors which could influence this validity are discussed below.

General historical events that may produce a pre-test post-test difference for group 1 such as pre-test ability levels or attainments may produce a different effect for group 2. The pupils were assigned at random to the groups to avoid this possibility. There may, however, be events in-between testing which may effect the treatments. For example, to run interviewing sessions simultaneously would have required different interviewers and their differences could have become a form of effect confounded with the treatment effect. The individuals were assigned at random to the interviews which for both pre-test and post-test were completed in five days. It was hoped to ensure by randomisation that events in-between testing were as common to the groups as possible and could not become a significant effect in explaining any differences observed. The three pupils in the experimental groups who failed to get the treatment were included in the results. This diminished the apparent effect of the treatment but avoided sampling bias.

The belief that more attention should be given by educational researchers to the analytic separation of variables will be emphasised by concentrating on the repeatibility of observations and detecting significant differences between experimental and control groups which can be assigned to the treatment in the hope that causal variables will be isolated and quantified.

"We should keep in mind that the successful sciences such as physics and chemistry make their advances without any attention to representativeness (but with great concern for repeatability by independent researchers). An Ivory-tower artificiality laboratory science is a valuable achievement even if unrepresentative, and artificiality may often be essential to the analytic separation of variables fundamental to the achievements of many sciences. But certainly, if it does not interfere with internal validity or analysis, external validity is a very important consideration especially for an applied discipline such as teaching".[4]

3) TREATMENT OF EXPERIMENTAL GROUPS

Six members of staff taught the Nuffield Combined Science Course[33] to the first year groups and each member had taught the course for the first time the previous year. Children from all groups in the first year were tested individually and the researcher was a frequent observer in all classes. This is simply to emphasize that the research was carried out as part of the normal day of a teacher and no groups appeared to children or teachers to be selected for special study. The assessments were arranged before and after school and so did not require the pupils being removed from their normal lessons.

Each experimental group had two teaching sessions of 1 hour 10 minutes per week. The control group investigated earthworms, a topic unconnected to the study of the treatment groups, estimating and measuring. The experiences of the children with a pendulum, milk straw weighing machine and mathematical beam balance were chosen for investigation to detect if a shift occurred in the pupils ability to abstract causal variables in these experiments as a result of the experiences.

a) THE PENDULUM

Each pupil in the treatment groups was given a booklet of worksheets containing instructions and questions. Six experiments including the pendulum experiments were completed by the pupils. The pupils changed from one experiment to another until they had finished the circus. There was no formal teaching but questions could be answered by the teacher and it was insisted that the worksheets were completed.

b) THE MILK STRAW WEIGHING MACHINE

The teachers demonstrated how to build the machine and the scale. Then the pupils with the help of the teacher and the instruction booklet built the machine and scale. One difficulty of carrying out true experiments within school departments was illustrated by one member of staff not being satisfied that his group understood how to construct the scale. He then taught one extra session to his group on how to construct the scale.

c) THE MATHEMATICAL BEAM BALANCE

The treatment groups experimented with the balance after receiving a demonstration. There was, however, a major difference between the two groups. One group received specific training to show the connection between mass and distance on each side of the fulcrum whilst the second group received guidance in the use of the balance as a weighing machine but the connection between mass and distance was not made explicit. This was an interesting observation because there is no specific reference to this connection in the worksheets but the teachers had access to the testing area during the post-test.

4) THE THREE EXPERIMENTS STUDIED

One behavioural criteria for a person who performs scientific experiments is to exclude one independent variable so that the effect of another, on the dependant variable, can be observed and quantified. If a scientist wishes to change a process in a predicted way he needs to isolate and quantify the causal variables in the process. The three experiments were chosen because each has several independent variables, which could effect the dependent variables. The pendulum had 1 causal variable affecting the period, the mathematical beam balance 2 causal variables affecting the position of equilibrium and the milk straw weighing machine 2 causal variables affecting its position of equilibrium.

a) THE PENDULUM

Dependent variables	:-	the period of swing
Independent variables	:-	mass
		length
		angle of swing
Causal variables	:-	length

b) THE MILK STRAW WEIGHING MACHINE

Dependent variables	:-	scale position
Independent variables	:-	position of screw
		position of needle
Causal variables	:-	position of screw
		position of needle

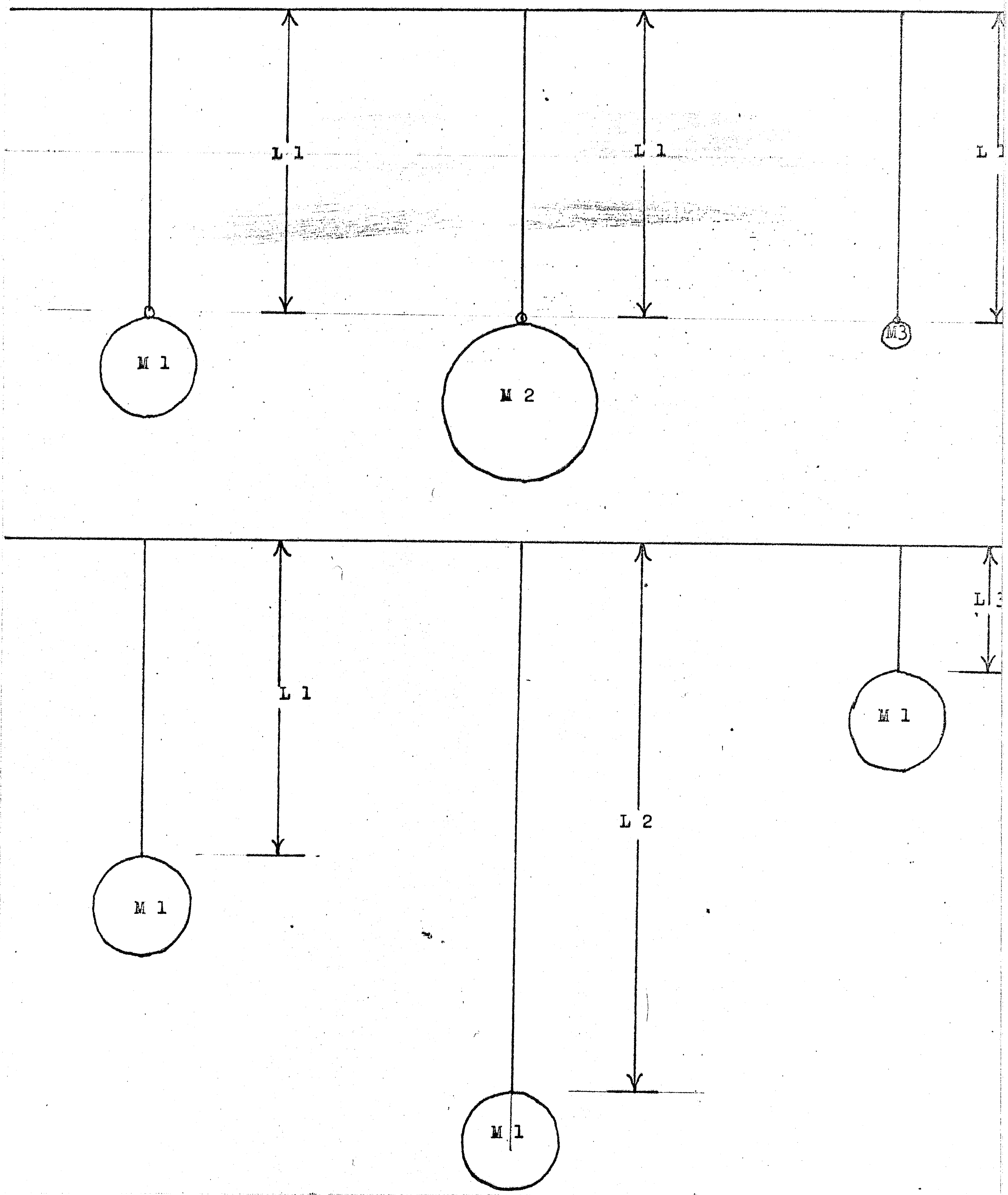
c) THE MATHEMATICAL BEAM BALANCE

Dependent variables	:-	position of equilibrium
Independent variables	:-	mass
		distance

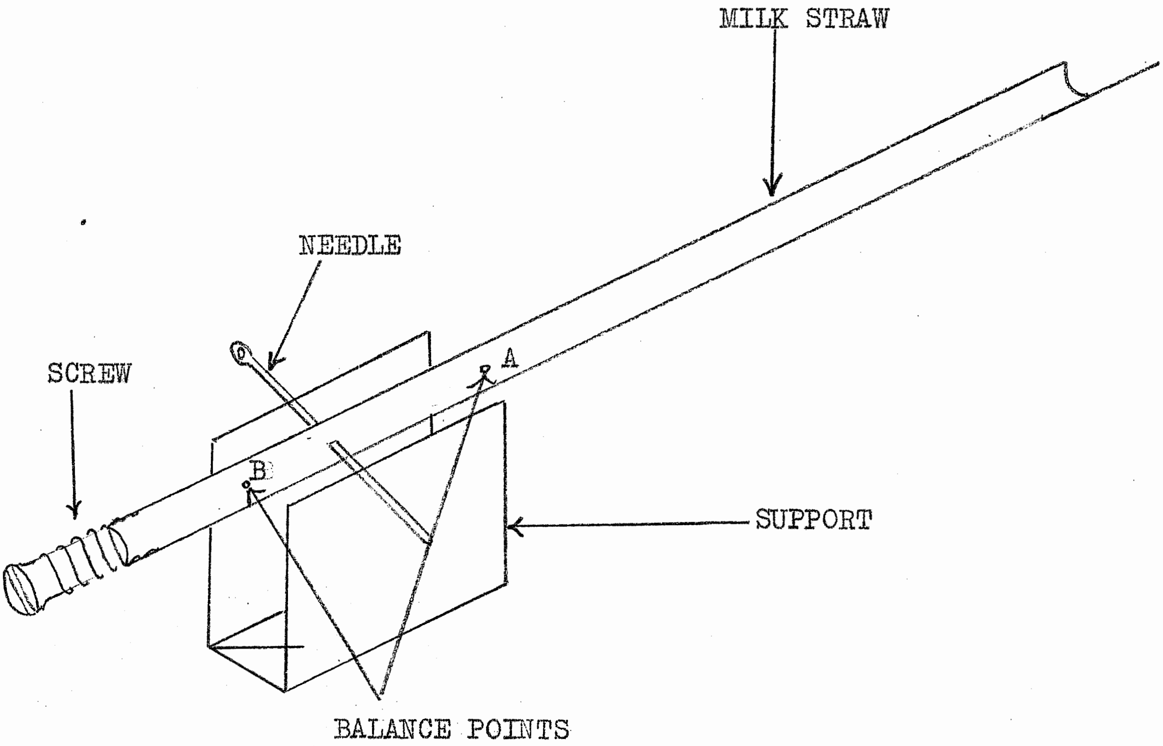
relationship between two independent variables which determines the position of equilibrium :- mass X distance.

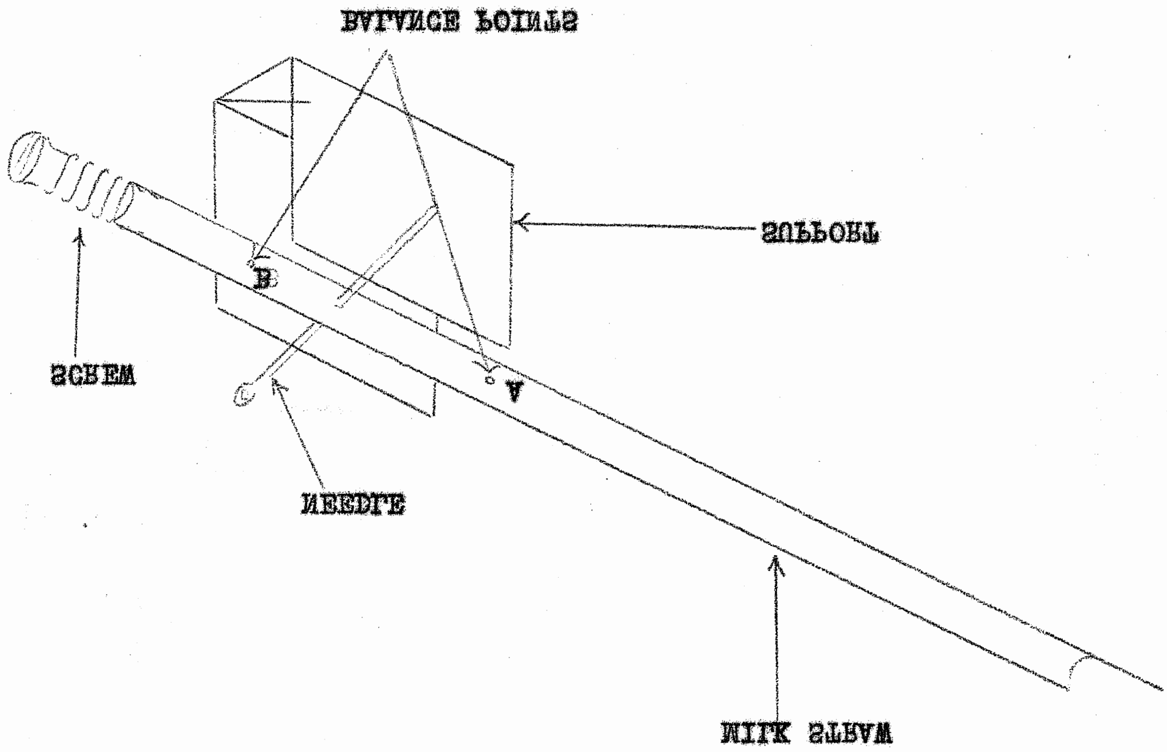
The diagrams of the apparatus used in the experiments and interviews, are followed by a description of the treatment of the experimental and control groups and details of the interviews used to measure any changes in the ability to separate out the causal variables.

THE PENDULUMS



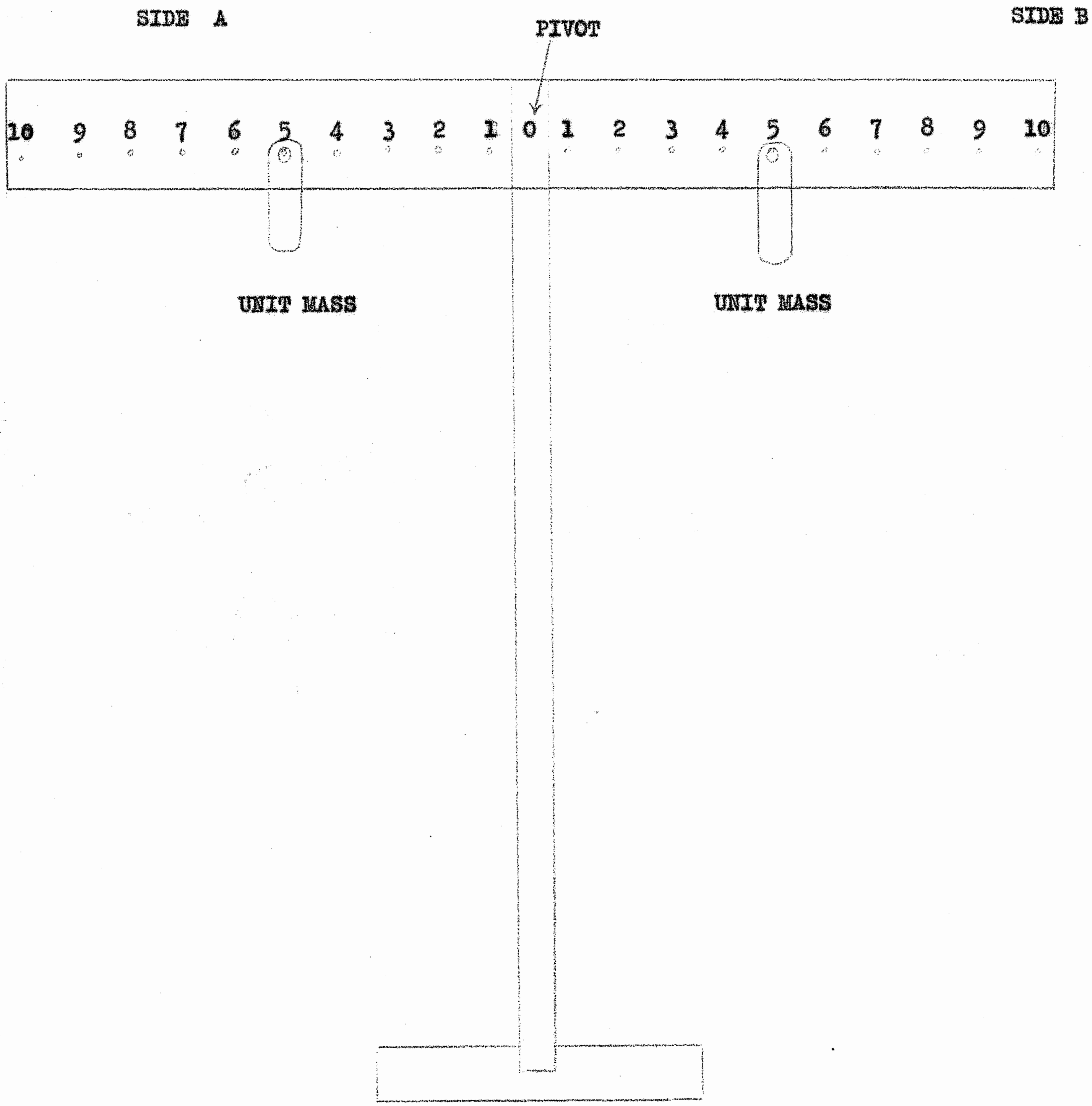
THE MILK STRAW WEIGHING MACHINE





THE MILK STRAW WEIGHING MACHINE

THE MATHEMATICAL BEAM BALANCE



5) THE INTERVIEWS

The interview is being used as a measuring instrument to detect the state of the adolescent's ability to choose the correct relationship between a dependent and independent variable.

A standardised interview[34] was designed for each of three experiments as the same information was to be collected from each respondent; the responses were to be classified and compared and differences observed between groups were, as far as possible, to be attributed to experimental treatments rather than reflecting differences due to questions asked or meanings attributed to the questions.

To avoid any differences in responses being due to the measuring instrument the standardised interview was scheduled, that is, the wording and sequence of the questions was predetermined and asked in the same way. The responses were recorded in pre-coded spaces. To produce a response that validly differentiated one response from another the stimulus must be as identical as possible. In each case the experiments were placed in front of the respondent (the visual stimuli were recorded on the schedule) to supplement the questions. Closed questions were given in each case as the purpose was to detect if the respondent could choose a response which stated the correct relationship between the dependent and independent variable.

The same interviewer was used in each case in the same place, to ensure that conditions were kept as constant as possible. Other factors which could influence the results independent of treatments given have been described with the experimental design.

A) THE PENDULUM

a) If I put a larger mass on the end of the string keeping the string the same length (pointing to the pendulum)

Q. Will one period (demonstrating a period of swing) take more time / less time / stay the same time?

b) If I put a smaller mass on the end of the string keeping the string the same length

Q. Will one period take more time / less time / stay the same time?

c) If I make the string much longer keeping the mass the same

Q. Will one period take more time / less time / stay the same time?

d) If I make the string much shorter keeping the mass the same

Q. Will one period take more time / less time / stay the same time?

B) THE MILK STRAW WEIGHING MACHINE

a) If I move the screw out a few turns (pointing to the screw as if to withdraw it)

Q. Will this side (Pointing to the screw side) fall / rise / stay the same?

b) If I move the screw in a few turns (pointing to the screw as if to screw it in)

Q. Will this side (pointing to the screw) fall / rise / stay the same?

c) If the needle is moved to here (pointing to position A)

Q. Will this side (pointing to the screw side) fall / rise / stay the same?

d) If the needle is moved to here (pointing to position B)

Q. Will this side (pointing to the screw side) fall / rise / stay the same?

C) <u>THE MATHEMATICAL BEAM BALANCE</u>

a) If I put 1 mass on here (pointing to A9)

Q. What will happen to your side? Will it fall / rise / stay the same?

b) If I put 1 mass on here (pointing to A10) and 1 mass here (pointing to B8)

Q. What will happen to your side (B)? Will it fall/rise /stay the same?

c) If I put 2 masses here (pointing to B5) and 1 mass here (pointing to A10)

Q. What will happen to your side (B)? Will it fall / rise / stay the same?

d) If I put 2 masses here (pointing to A5) and 1 mass here (pointing to B10)

Q. What will happen to your side? Will it fall / rise / stay the same?

e) If I put 1 mass here (pointing to A9) and 3 masses here (Pointing to B2)

Q. What will happen to your side? Will it fall / rise / stay the same?

6) HYPOTHESES TO BE TESTED

1) There will be no difference between the pre-test means for the total group scores

2) There will be a difference between total scores for groups 1 and 3

3) There will be a difference between total scores for groups 2 and 3

4) There will be no difference between groups 1 and 3 for unguided discovery

5) There will be no difference between groups 2 and 3 for unguided discovery

6) There will be a difference between groups 1 and 3

7) There will be a difference between groups 2 and 3

8) There will be a difference between groups 1 and 2 for guided discovery and specific training.

RESULTS

a) PENDULUM

MASS INCREASE					MASS DECREASE				
PRE		POST				PRE		POST	
right	wrong	right	wrong	group	group	right	wrong	right	wrong
3	15	1	17	1	1	3	15	2	16
2	16	3	15	2	2	3	15	6	12
0	18	1	17	3	3	1	17	0	18
LENGTH INCREASE					LENGTH DECREASE				
PRE		POST				PRE		POST	
right	wrong	right	wrong			right	wrong	right	wrong
7	11	9	9	1	1	9	9	11	7
10	8	10	8	2	2	10	8	13	5
10	8	14	4	3	3	10	8	11	7

Groups 1 and 2 are the treatment groups group 3 is the control group.

13

b) THE MATHEMATICAL BEAM BALANCE

1 A 10					1 A 10 1 B 8			
right	wrong	right	wrong	Gp	right	wrong	right	wrong
pre		post			pre		post	
18	0	18	0	1	10	8	13	5
18	0	18	0	2	14	4	14	4
17	1	18	0	3	9	9	10	8
2 B 5 1 A 10					2 A 5 1 B 10			
11	7	17	1	1	12	6	17	1
12	6	15	3	2	11	7	13	5
6	12	8	10	3	3	15	6	12
1 A 9 3 B 2								
11	7	14	4	1				
3	15	7	11	2				
6	12	8	10	3				

RESULTS CONTINUED

THE MILK STRAW WEIGHING MACHINE

SCREW OUT					SCREW IN			
PRE		POST			PRE		POST	
right	wrong	right	wrong	Group	right	wrong	right	wrong
8	10	13	5	1	8	10	12	6
6	12	17	1	2	4	14	13	5
11	7	13	5	3	7	11	7	11
NEEDLE AWAY					NEEDLE TOWARD			
right	wrong	right	wrong		right	wrong	right	wrong
8	10	11	7	1	6	12	8	10
14	4	15	3	2	7	11	10	8
9	9	13	5	3	8	10	8	10

8) TREATMENT OF RESULTS

A) ANALYSIS OF COVARIANCE APPLIED TO A SINGLE FACTOR EXPERIMENT

Two problems confront the educational researcher on analysing his results. How does he assign observable effects to his treatments within known limits of error and what are the assumptions underlying his analysis? For a researcher interested in the analytic separation of causal variables so that changes in educational practice can be controlled, the statistical analysis below has the disadvantage that a correlation between two sets of scores implies a functional relationship but does not imply a causal relationship. Consideration will now be given to how the analysis of covariance applied to a single factor experiment allows the analysis of the variation of the post-test means to be made independent of variation in the pre-test means[35].

The basic structural model for this single factor experiment is assumed to be:-

$$\overline{Y}_i = u + T_j + E_{ij}$$

Y_i is a criterion score

u is an unknown constant

T_j is constant for all elements within a treatment population but may differ for different treatment populations depending on the difference between the means of the treatment populations.

E_{ij} is a component depending upon uncontrolled sources of variance. As the pupils observed after each treatment were assigned at random to these conditions one has some degree of assurance that the error effects will be independent of the treatment effects.

We wish to assign differences in the post-test means to our treatments independent of variations in our pre-test results. The method used to adjust the post-test scores for the influence of the pre-test scores was to calculate the average effect of an increase of 1 unit in the covariate, that is, the pre-test score, upon the variate, by a regression analysis. The form of this analysis is illustrated below.

In terms of a linear regression an adjusted criterion mean has the following form:-

$$\overline{Y}_j' = \overline{Y}_j - b\ (\overline{X}_j - \overline{X})$$

where b is an estimate of B the population linear regression co-efficient.

We can obtain the adjusted criterion mean in terms of the basic linear model underlying the analysis of variance:-

$$\bar{Y}_j = u + T_j + E_{ij} + B(\bar{X}_j - \bar{X})$$

$$Y_j' = u + T_j + E_{ij}$$

The influence of the covariate has been removed by linear regression. This means that the variations in the adjusted criterion means are not independent and there is sampling error in the estimation of B. For these reasons the variation in the adjusted criterion means are not used in the tests of significance but the residual sum of squares is used to provide variance estimates for the F ratio. In this analysis the residual variation about an overall regression line is divided into two parts. One part is a function of within class residual variation, the second part, the reduced sum of squares due to treatments is a function of between class variation. The assumptions of the analysis are that treatment effects and regression are additive with the implication of homogeneity of within class regression. The assumption is also made that the residuals are normally and independently distributed with zero means and the same variance.

B) HYPOTHESIS TESTED USING STATISTICAL ANALYSIS

HYPOTHESES	F. observed	F. for significance at .05 level
1	.1002	3.23
2	2.99	4.28
3	2.86	4.28
4	.47	6.61
5	.22	6.61
6	7.30	6.61
7	2.87	6.61
8	6.17	5.59

9) DISCUSSION OF RESULTS

Hypothesis 1:- No difference between the pre-test means for the total group scores.

The resultant F value of .1002 was expected as the pupils had been randomly allocated to their groups, a factor which should ensure no difference between the means for the pre-test results.

Hypotheses 2 and 3:- A difference between the means for the total scores of groups 1 and 3 and 2 and 3.

Although the gain scores were higher for the treatment than for the control groups the analysis of covariance did not detect a significant difference between the variation in the post-test scores which was independent of the pre-test scores. This negative result could be explained in several ways. One effect which is sometimes found with this experimental design is that the pre-test has a sensitising effect on the subject. The effect due to the pre-test cannot be removed due to the design. It could, however, be accounted for if a Soloman four groups design had been used and it is suggested that this design is used in large schools where the pupils can be randomly allocated to four groups within an ability band or in a school with mixed ability groups. This latter system is preferable as it would allow randomisation within a year group. The second factor which could account for the negative result at the 5% level of significance is the instrument used. In an attempt to simplyfy the instrument to measure the major change which would have occurred if the scientific objective had been attained, the interview is insensitive to changes which may have occurred in the adolescents understanding of the factors involved in the experiments. It is proposed in future to supplement the interview with an objective test which may perhaps be more sensitive in detecting changes in scientific thinking.

Hypotheses 4 and 5:- No difference between groups 1 and 3 for unguided discovery. No difference between groups 2 and 3 for unguided discovery.

The F values of .47 and .22 gave no difference between the treatment and control groups. The pupils did not detect the causal connection between time and length even though they had carried out experiments following instruction sheets 4 and 5. This result corresponds to Piaget's assertion that pupils at eleven years old will be unable to isolate variables and discover causal connections. The negative result could be due to the method of unguided discovery used. The experiments were designed to estimate and measure time. It was hoped, however, that the pupils with the help of the instruction sheets would discover the fact that mass has no effect on the period, andlength is the only causal variable.

Hypotheses 6 and 7:- There will be a difference between groups 1 and 3 and between groups 2 and 3.

The positive result for hypothesis 6 is as expected, the experience of knowing how to build the milkstraw machine has produced a significant change. In group 2, however, no significant change was produced. The main reason for this is thought to be that group 1 spent one hour more experimenting with the milk straw machine than group 2.

Hypothesis 8:- There will be a difference between groups 1 and 2.

The F value of 6.17 shows a significant difference exists. The group receiving specific training showed a marked improvement in their comprehension of the connection between the two variables and the position of balance over the group which received guided discovery.

10) CONCLUSION

The study has demonstrated the feasibility of carrying out this type of research within a school with a teacher as educational researcher. It has not detected the state of formation of scientific concepts or isolated and quantified causal variables in the transmission of valued knowledge. This was probably due to the inadequate instruments used. Success, where this study has failed, could rest upon the development of reliable tests of fundamental and relational concepts with content and construct validity. As a first step, visual, verbal and written records could be gathered of children and adolescents doing science, so that educators begin to develop operational definitions of what meanings children construct from their experiences. That is, the researchers need the child's account. Groups of infants, children and adolescents could be studied as they progress through primary and secondary schools. Video tapes, attitude and interest tests together with tests of cognitive attainment could be used to measure the effects of treatments on the adolescents consciousness. We may then be in a better position to state what changes in children and adolescents the treatments in schools are designed to produce, to measure the changes produced and to alter techniques so that they are more effective in producing the desired result, that is, scientific understanding in children and adolescents.

The possibilities of carrying out this research could depend upon the control of education, about which little is known. It is perhaps unjustified to infer too much into the fact that of 111 projects reported to the Schools Council Document Projects in June 1971, 76 were situated in Universities, 11 in Colleges of Education and 2 in Schools. These figures would seem to be an indication, however, of at least one largely unquestioned assumption[36], educational research is best done in Universities. It may be that the effectiveness of the transmission of valued knowledge within schools would be improved by situating more projects within schools with teachers as educational researchers.

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