COMMUNICATIONS

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Taxonomies and Hierarchies: Theories and Implications**

Taxonomies arise from acts of classification, from the recognition of similarities and differences, of use and avoidance, and their continuation by the application of names and titles. As one very cogent definition says, "A true taxonomy is a set of classifications which are ordered and arranged on the basis of a single principle or on the basis of a consistent set of principles. Such a true taxonomy may be tested by determining whether it is in agreement with empirical evidence and whether the way in which the classifications are ordered corresponds to a real order among the relevant phenomena. The taxonomy must also be consistent with sound theoretical views available in the field . . . Finally a true taxonomy should be of value in pointing to phenomena yet to be discovered." Of the taxonomies available, plant taxonomies are the best known, with a well documented history.

Plant naming was an important aspect leading to a taxonomy. With the invention of printing it became more important to match names with illustrations — a primitive form of ostensive definition. By 1688 one great step forward was taken by John Ray who first used consistently a single classifying principle, allied with a rigid determination to remove the essential from the adventitious. This basic work made possible the presentation of natural groups and the relations between them. Linnaeus, on the other hand, started from the perception of clusters of similarities, and with one single principle of classification was able to produce an enduring descriptive system. This started with a generic name, followed by a specific epithet, and a description, and has remained as the most inclusive method for identification of plants.

We are reminded that a classification may serve two different though related purposes;—

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1. it may enable us to identify the class to which an object belongs.
2. it may enable us to display the relationships of different kinds of objects, their resemblances and their differences.

Linnaeus' work was a work of classification and identification, a taxonomic key. Ray's work, on the other hand, helped reveal relationships, and it is relationships which have proved to be the most important aspect of modern taxonomies of plants and animals.

Darwin's *Origin of Species* affected biological taxonomies by stressing common ancestry, which, schematically, demanded geneological linear branching. More recently, consideration of the competition - collaboration duality in biology has shown even more forcibly such biological systems are connected in a set of hierarchical levels. Somewhat later, in physiology, there was Hughling Jackson's notion of "levels" within the nervous system, with the control of function being exercised by the spinal cord, the medulla and cortex, was hierarchical in conception and formed the basis of Sherrington's later exposition of the inhibition exercised by the "higher" levels upon the function of the "lower" centres. In turn this influenced Burt in his portrayal of the structure of the mind as essentially hierarchical, from which may stem his hierarchical group factor theory of intelligence, and his concept of sub - divided factors.

We should perhaps note two psychometric considerations as being relevant here. These refer to the two matrix forms of correlation coefficients as found by Guttman, the "simplex" and the "circumplex". In the former the highest correlations are found along the major diagonal, the next highest correlations along the lines parallel to the major diagonal and one cell removed, and so on. The lowest correlations are found at the top right and the bottom left of the columns. In the latter each column has the same total and each row contains the same entries as the preceding row, moved one place to the right.

We are now in a position to examine the application of a taxonomic classification to cognitive tests, in particular to Bloom's *"Taxonomy of Educational Objectives: Cognitive Domain."*, a taxonomy designed to fulfil several purposes. In the first (p. 10) place the taxonomy was designed to facilitate communication about educational objectives, that is for identification in terms of symbols chosen to represent educational outcomes. In the second place it was designed to be a classification of student behaviours, that is, what systematic teaching was expected to elicit. In the third place it had to order phenomena in ways which would reveal some of their essential properties as well as the interrelationships among them. These notions of ordering behaviours were introduced so that the more complex behaviours would include all the simpler ones; their principle of complexity was not just Herbartian in conception, but partook of scale properties in Guttman's terminology. Thus, their taxonomy was conceived as a hierarchy of knowledge, comprehension, applica-

tion, analysis, synthesis and evaluation. They further intended that the same hierarchy should apply at all ages, and for all kinds of educational content.

When it was desired to extend the taxonomy to a second domain, that of affective processes, difficulties were encountered. There was no great residue of expert knowledge, as in the cognitive domain, and no clear tests had been previously constructed. There was less common ground amongst workers in this domain, less conviction that specification of affectional objectives would influence examiners in the construction of tests. Finally, there was no readily acceptable ordering principle, as 'complexity' had been in the cognitive domain. However, by the use of stipulative definitions of zones along a continuum of 'internalization' they were once more able to produce a taxonomy. 'Internalization' is not unidimensional, so the concept of a continuum of a multidimensional referent is lacking in rigour. Modern general systems analysis would indicate that the hierarchical nature of 'internalization' with sub - systems at the nodes of 'organization', 'valuing', 'responding' and 'receiving' would enable one to accept that the idea of a continuum was only a crude first approximation. Apt illustrations from the realm of mammalian physiology would provide obvious analogies. Milsum for example, has considered such important systems as "the cardiovascular system for blood circulation, the respiratory system for gas exchange with the environment, the thermoregulatory system for heat exchange with the environment, the endocrine system and finally the central nervous system itself. Physically these systems all share the blood circulation, but in more or less dependent ways; furthermore they affect each other to various extents". Each of the systems can be, and has been, studied separately as though independent, but it is nonetheless evident that there is hierarchical control of the systems through the central nervous system. There has been independent study of interests, appreciation, attitudes and adjustment; control is vested in some internal organizing principle here referred to as 'internalization'.

Most teachers are prepared to use these taxonomies as identifying devices, as aids to a more unified discourse about educational objectives. But it is possible to test whether or not the hierarchical order does emerge in practice. Two assumptions must be made. First it must be assumed that the order of complexity is as stated by Bloom, from knowledge to evaluation. It must also be assumed that a correlation coefficient represents a measure of common elements. Then we can argue that the correlations between neighbouring elements will be greater than between more remote elements, being least between tests of knowledge and tests of evaluation. Thus, the test for hierarchical order is whether or not the matrix of intercorrelations can be rewritten to meet the specification of the simplex structure.

Bloom suggested that the taxonomy would prevail for all kinds of educational content. It may be presumed that correlations between knowledge of different kinds of content would be higher than that between knowledge of one content and evaluation of another content. If it were possible to construct tests for, say, three different kinds of content, and for six levels of the hierarchy (or taxonomy) then the 18 x 18 matrix of correlations should show the circumplex pattern. Conventional factor analysis should produce six factors corresponding to the elements of the hierarchy.

A great many problems of test construction would have to be solved *en route* to the production of a sufficiently large number of test items for adequate testing of the taxonomy and its hierarchical order. Usually complexity within an item has been a device to increase the difficulty level of the test item. If all knowledge items were simple, and all evaluation items were complex, a factor analysis might only be factorizing difficulty. Despite this, after fourteen years, the amount of research on the validation of the cognitive domain taxonomy is still disappointing; of the affective domain taxonomy virtually non - existent. The most important single effort to validate the cognitive taxonomy was made by Kropp and Stoker whose work was published in 1966. In grades ten, eleven and twelve they found a fair approximation to the circumplex form of matrix, giving some measure of support for the taxonomy in different content areas. For one kind of content they found a fairly clear simplex structure, giving further support to the hierarchical nature of the taxonomy. Validation of the taxonomy is likely to be a time consuming and highly complex process. Withdrawal of financial support by the U.S. Office of Education has virtually eliminated any further large scale testing of this work.

In the absence of such validation we are once more in the realm of belief, and speculation. Some ten years ago Humphreys showed how repeated testing of a function presumed to increase with practice, as in the work of Fleishman and Hempel, would yield a simplex structure. He also demonstrated that any function subject to growth would also yield a simplex structure. Is it also possible that the converse is true — that obtaining a simplex structure guarantees that one has been testing a function which grows? In the affective domain that would raise some interesting speculations in terms of either Freudian stages, or Havighurst's developmental tasks. In the cognitive domain it could raise speculation about "readiness" for each of the stages beyond knowledge. This line of speculation would also seem to lead to some consideration of Gagné's work, on the *Conditions of Learning,* especially when it is remembered that he was not involved in the construction of either taxonomy. Independently he produced a hierarchy of learning processes, with each process being dependent upon lower ones in the hierarchy, and each being related to the conditions under which learning might take place.

It should not be forgotten either that the taxonomy has been criticised by Guilford. Four of the six of Bloom's cognitive processes fall within the cognitive domain of Guilford, which has twenty four cells. Bloom's 'synthesis' appears to be related to 'productive thinking operations' in Guilford's terminology, whilst 'evaluation' would be an operation category within the Structure of Intellect Model. To Guilford, Bloom's concepts carry redundancy, or, Bloom is a "lumper", and to Bloom, Guilford is a "splitter". This apart, the taxonomy has provided a classification of some common educational objectives about which teachers can now communicate more effectively as a result of clear identification. The attempted validation has raised important problems for test constructors. It has revealed some interesting deficiencies in their modes of functioning. But at best, the taxonomy can only be regarded as a halfway stage to the specification of behavioural objectives which can also be expressed in terms of other functional and verified psychological concepts and dimensions.

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Social Trends and Educational Planning**

The only way that we in education can reduce some of the fears we have about what the future holds for us is to examine where it is we appear to be going. There is a need for some tentative answers to questions paralleling those put recently by the economist William Peterson: for example, what will be the future public demand for education at various ages and levels? What kinds of subjects and new learning technologies should be under development to get ready for the future? How large and how skilled does the teacher and teacher aide force have to be? What kind and how much physical plant capacity shall be required to meet the probable social needs of the future? These are fairly obvious questions but their answers may not be all that obvious because they arise out of some broader questions like what are the directions and growth rate of the economy in the future? Or, what will be the socio-political structure of values and institutions under which education will operate?

If consideration is given to the Canadian case, although Canadian society has essentially taken shape in an evolutionary way — evolutionary in that it has come to its present state of affairs as a modern complex

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