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MULTIDISCIPLINARY SUBJECTS: EMERGENCE, STRUCTURES, DEVELOPMENT AND CLASSIFICATION.

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Emergence of multidisciplinary subjects is a socio-economic necessity of current day life. They are supported by a variety of sponsors such as governments, institutions, missions at the international, national and local levels. Curiosity and creativity of individuals have accelerated the emergence of multidisciplinary subjects. This paper discusses the ways and means of development of such subjects.

The indication of these developments can be seen by the emergence of different kinds of publications of books, conferences and periodicals. The library classification schemes and other devices used for information retrieval are keeping pace with these developments. For this purpose, models for development of much disciplinary subjects are identified.

1 Introduction

Knowledge is a formless stream. It is everchanging. However, the utilisaton of knowledge and transmission of the same across space and time has necessitated the need for imposing a structure on knowledge. The philosophers have imposed structures on knowledge. They are of several varieties. It is the result of an interplay, as A N Whitehead, puts it of "three notions of the variable, form and generality (who) compose a sort of mathematical trinity which preside over the whole subject" (40). Historical tracing of the structure of knowledge based on one variable or other is presented in Flint's book (10) and by E C Richardson (35) and B C Vickery (38). Yet the very dynamics of the evolving new structure

of knowledge has made it unstable. To that every individual adds an irrational "Just so-ness" aspect in the perception of knowledge. It is just like water. It takes the shape of the container. It takes the colour given to it. In order to understand knowledge, an individual and groups of individuals, have divided knowledge into disciplines, a sort of coherent, homogenous sub-wholes. This is to improve productivity in communication in teaching, learning and problem solving processes. Disciplines such as Physics, Chemistry, Mathematics, Economics and Law are the result of evolved theoretical frame-works enunciated in the form of laws, canons, and principles. Theories are evolved in a developmental phase of a subject field. It is characterised by a spiral of scientific method as projected by S R Ranganathan (32). They simulate a paradigm-oriented structure and development as projected by Thomas Kuhn (15). The general schemes for classification of subjects such as DC, LC, IDC, BC and CC have adopted their basic structure from this discipline-based division of knowledge.

Such discipline-oriented classification of knowledge provided good support in academics. But when knowledge began to be used as input for human progress, the utility of this classification began to wane. The Phenomenon of technology transfer began to dominate in human development. In this we find a focal point for the convergence of many conceptual, ideological and practical paths. The convergence is towards a goal to solve the practical problems of humanity.

To quote Thomas Aquinos "It belongs to *wisdom* to direct all sciences and arts in an orderly way towards one thing, that is, the *perfection of man* which is his happiness" (1).

This involves a networking of several disciplines, sub-disciplines, fragmentations and atomisation to a new focal point. The focal point itself is a choice of the culture of society. Such an activity leads to problem-focussed research. This leads to what is called multidisciplinary and interdiscipinary subjects.

2 The Emergence

Multidisciplinary and interdisciplinary subjects were in existence in a low key before World War II. In 1922, Herman Muller, hinted the need for interdisciplinary research in identifying the

structure of DNA. He said "must the geneticists become bacteriologists, physiological chemists, and physicists simultaneously with being zoologists and botanists? Let us hope so?" (17). It proved prophetic. The interdisciplinary exchanges that were critical in the discovery of the double helix structure of DNA in 1953 is indicated in the following passage of James Watson. "The unforeseen dividend of having (American Crystallographer) – Jerry (Donhue) share an office with Francis (Crick), Peter (Pauling) and me though obvious to all, was not spoken about. If he had not been with us in Cambridge, I might still have been pumping for a like-with-like structure. The tautomeric forms I had copied out of Davidson's book *(The Bio-chemistry of nucleic acids)* were in Jerry's opinion incorrectly assigned. My immediate report that several other texts also pictured guanine and thymine in the enol form cut no ice with Jerry. Happily he let out that for years organic chemists had been arbitrarily favouring particular tautomeric forms over their alternatives on only the flimsiest of grounds..... Maurice Wilkins, in a laboratory devoid of structural chemists, did not have any one about to tell him that all the text book pictures were wrong. But for Jerry, only Linus Pauling would have been likely to make the right choice and stick by its consequences" (39).

These were research for quenching curiosity. But war brought into focus the need for interdisciplinary research as a necessity. Von Newmann lists unorthodox collaborators from 13 disciplines from astronomy to zoology, physics and paleantology and mathematics to psychology, Newmann says, "Mathematicians discussed gunnery problems with British soldiers in Burma; chemists did bomb damage assessment with economist colleagues at Princes Risborough, a "secure" head quarters outside London, generals conferred about tank strategy in the Italian campaign with biochemists and lawyers, a famous British zoologist was key man in planning the bombardment of pantellarea, naval officers took statisticians and entomologists into their confidence regarding submarine losses in the pacific, the high command of the R.A.F. and American Air Force shared its headache over Rumanian Oil fields, French Marshalling yards, German ball bearing and propeller factories and mysterious ski sites in the pas-de-calais with psychologists, architects, pale-antologists, astronomers and physicists. It

was a lively, informal, paradoxical exchange of ideas between amateur and pofessional war makers and it produced some brilliant successes. It led to the solution of important gunnery and bombardment problems; improved the efficiency of our antisubmarine air patrol in he Bay of Biscay and lsewhere; shed light on conveying methods in North Atlantic, helped our submarines to catch enemy ships and also to avoid getting caught; supplied a quantitative basis for weapons evaluation; altered basic concepts of air to air and naval combat; simplified difficult recurring problems of supply and transport. There were of course many more failures than successes. But the overall record is impressive" (27). This was a work of mission, a practical need to collaborate. The enthusiasm was infectious. Bronowski explains, "A war or a battle, a mision or a problem none is repeatable and none is an experiment. Yet the young scientists brought with them the conviction that in them and nowhere else must be found the empirical evidence for the rightness or wrongness of the assumptions and underlying strategy by which war is made. The passion of these men was to trace in operations involving life and death – the tough skeleton of experimental truth" (6).

It was again during World War II, Prof P M S Blackett gathered men from different disciplines to solve the problems in the battle of Britain. In August 1940, he collected an unorthodox group. It consisted of three physiologists, two mathematical physicists, one astrophysicists, one army officer, one surveyor, one general physicist, and two mathematicians. It was known as Blacket circus. The exegencies of war that demanded the interchange across disciplinary barriers served in a large measure, to hammer out a new methodology which had as its object, the operational responsiveness to the practical problems of winning a war. Thus group of interdisciplinary exchanges gave birth to "Operations Research" and later on to "systems analysis" (36).

However, multidisciplinary problem focussed research is identified because of the prior existence of disciplinary structure of knowledge. Otherwise, one could as well have referred to the puresciences as multidisciplinary since they incorporate from distillations knowledge derived from several disciplines. This is not done probably due to the circumstances that the problem focussed reearch has grown out of pure sciences. The application of latter in

synergistic relation to a problem focussed situation and the amalgamation and synthesis of results of multidisciplinary exchanges have led to problem focussed research to create multidisciplinary and interdisciplinary subjects.

Viewed from the point of view of unified knowledge, these interdisciplinary subjects are products of the ontology of differentiation (analysis) and integration (synthesis). Such an activity will use the language of theoretical construct and experimental techniques of different disciplines in problem solving. An effective dovetailing of these would lead to a new theory and language (jargon) and a new interdisciplinary subject. The study of complexities of the systems such as the oceans, the environment, brain and behaviour, energy, materials, computers, and space attract attention from multidisciplinary approaches.

3 Modes of Interaction

Multidisciplinary subjects emerge in several ways. A typology of the modes of emergence can be categorised into the following (18):

1. Juxtaposition of studies on a phenomenon;
2. Borrowing of data;
3. Borrowing of tecniques and tools;
4. Borrowing of principles and theories; and
5. Convergence of view-points.

These modes are incident in a gradual manner. They are not mutually exclusive. It can move from an aggregation to a coherent confluence of ideas as we move from stage 1 to stage 5.

1. The juxtaposition of studies is the result of work done in different fields of knowledge on a single problem brought together in a symposia, report or handbook. They appear to be parallel study of various aspects of single problem or phenomenon. The association appears to be merely a physical proximity. It is an initiation of interaction among disciplines.

2. Interdisciplinary approaches can also be promoted using data borrowed from one discipline for use in another. Such a borrowing does help in the conservation of research potential by minimizing unnecessary duplication of effort. Thereby it also accele-

rates the development of the receiver discipline as well as lending discipline.

3. One of the commonest ways in which interdisciplinary subjects arise is by the borrowing of techniques and tools developed in one discipline by another. The application of measuring techniques, mathematics, logic, statistical techniques, in such fields as physics, chemistry, biology, agriculture, medicine, linguistics, psychology, political science, economics and sociology are good examples illustrating the phenamenon of interdisciplinary borrowing. These applications have largely been adopted in problem-solving or model development in the borrowing field.

4. Theory of a discipline developed in the form of laws and principles may be applied for the development of the theoretical base of another discipline. This association provides a closer bond between the interacting subjects, than the other types of association. Piaget (29) calls such an association as "hybridisation" with fruitful recombination or mutual enrichment.

5. The research workers in different disciplines tackle the same problem simultaneously and synchronise their efforts, exchange findings, and draft separate reports and have an interdisciplinary dialogue and integrate their findings into a final report or study. In this instance what is sought is a clustering, convergence and distillation of a confluence of specialists on a problem. It is team research.

4 Methods of Developments

The development of interdisciplinary subjects essentially depends on the linkage effected or focussed on particular problem. Conscious attempt to encourage persons from different discipline to focus attention on a problem, phenomenon, or mission becomes imperative. Once a problem has been chosen, the encouragement for research in the area should be pursued systematically. It can be done in three stages. The first step would be to create awareness among the relevant scientific community on the significance of problem chosen. The research fertility of multidisciplinary activity in the problem-area should be highlighted. The scope for social re-

cognition and utility of the problem focussed research may have to be projected.

The second stage of development is to effect communication or transaction between the various scientific disciplines used in the problem area, as an interim stage towards a common language. The coordination of the fragments and their interpretation became important. An interdisciplinary language is needed. It should be able to promote interdisciplinary thinking and reasoning. The interdisciplinary language is a product of synthesis of fundamental and functional — the pure and applied merged in appropriate proportion to promote development. In essence a synthesis of the complementary elements in the allied disciplines have to be evolved. It is a kind of synergism.

The third stage is to lead towards action. Setting up experiments that need expertise from divergent fields or disciplines and integrating the results of studies from different disciplines. Such an approach would fashion out to a more comprehensive understanding of a phenomena or problem. An understanding more complete than the sum total of disciplinary studies.

The encouragement for such studies should be continuous and perspective. Government support is essentially for promoting interdisciplinary activities. Universities and advanced research centres effectively provide for organic analysis and synthesis of interdisciplinary activities. A typical programme for the development of interdisciplinary studies is presented in Table 1. It indicates the roles of different of groups persons involved in the promotion of interdisciplinary activities.

5 Factors Promoting multidisciplinary approach

Multidisciplinary approach is dependent on several factors for its promotion (3). They can combine or oppose each other in many different ways. But the factors contribute to the development of multidisciplinary subject. They are grouped as follows:

Table 1 : **Programme of support of interdisciplinary activity :**

The Role of Different Groups persons involved in the promotion of interdisciplinary activity.

Group Agency	Step 1 Creating Awareness	Step 2 Development of communication	Step 3 Experiments
Scientists	Organic multi-disciplinary groups. Discussion groups/ Societies etc. Organise colloquia on new problems involving interdisciplinary subjects.	Broaden the subject scope of existing media for scientific communication such as periodical publications, conferences, invisible colleges, to accept the multi-disciplinary approach to problem-solving.	Encourage and support appointments and other rewards for the scientists working beyond the limits of a discipline. Enlarge discipline. Enlarge discipline breaking interest of individuals.
Universities	Encourage multi-disciplinary meetings/activities. High light the problems needing multidisciplinary approach. Problem-focussed research.	To organise course curriculum and institutes with multidisciplinary interest. Encourage publication of multidisciplinary activity.	Promote research collaboration, minimize bureaucratic influences, bring in inter-departmental projects; promote centres of advanced studies involving interdisciplinary activity.
Governments	Encourage multi-disciplinary research, through the establishment of research councils, identify the potential for promising multidisciplinary areas, and provide for a wide dissemination of information.	Support multi-linary research study groups, conferences, training courses, support multi-disciplinary journals.	Support multidisciplinary laboratories and institute provide interdisciplinary transactions. Establish Mission-Oriented, problem focussed projects and create centres of excellence.
International Organisations	Encourage international Multi-disciplinary training courses and programmes for young scientists project multidisciplinary societies.	Organise international multi-disciplinary programmes, conferences, institutes, directories periodical publications etc.	Support joint planning by major research centres on key problems create funds international awards in multidisciplinary research and coordinate work of international research centres for the promotion of multidisciplinary research.

(A) Encouragement

1. There is a continuous emergence of problem in societal level and the stimulus and consciousness for concerted research in solving the problems. It gives impetus to promote multidisciplinary research;

2. The utility value of problem focussed research is more obvious than otherwise. Medical, Legal, Engineering and Agricultural research have tacit utility value. The combination of these coupled with social economic status gives excellent scope for the study of any aspect of a society, say women, backward class, rural group, urban groups, elites etc.

(B) Contact-Node for research

1. Crystalized ideas and solid basis for problem oriented research can be identified.

2. Communication facility for contact with a team of specialists exists. Dialogue on solutions for same or similar problems takes place. Invisible colleges and interdisciplinary dialogue should be promoted.

(C) Contact-Node for Problem-Recognition

1. Direct contact with the nature and society brings contact between specialislts, research workers, and the possible beneficiaries of research.

2. Project-oriented continuous research should be promoted. Points of problem recognition, research-focus, and the points of utilisation should be an interwoven one.

(D) Action-Oriented Research

An appropriate mix of contact between pure research, applied research, developmental research, and practical problem solving is to be fostered. There should not be overly domination of any one of these activities.

(E) Support-Facility

Appropriate institutional infrastructure and switching mecha-

nisms to support interdisciplinary activity is needed. The greater the encouragement better the movement of interdisciplinary problem-solving.

Strategic, tactical and operational planning is to encouraged with facility and ease. The benefit of work plans should be fedback to strategic and tactical planning process.

(F) Inter-disciplinary Associations

Inter-disciplinary associations are to be promoted and fostered at the local, national, international levels and communication channels, formal and informal are to be developed.

(G) The Impetus

The existence of a common-rallying point, a common designation, professional identification, the organization of congress as seminars and symposia, the existence of information and communication media, common to a field of problem-focussed research all these are factors which lead toward a coherent and continuous progress towards interdisciplinary research.

6 The Growth of Multidisciplinary Subjects

61 Contribution of Mathematical Methodology

The multidisciplinary subjects have grown in large numbers. The barriers of disciplines are steadily broken to create newer subjects. The earliest of these is Mathematics or Mathematical sciences. It has moved into almost all the disciplines in the universe of subjects from physics, chemistry, biology to psychology, economics and sociology. The use of mathematical models is primarily to increase predictivity and to subject to to rigorous scientific method. The application of mathematical methodology for pure-theory development, or induction of data into mathematical statistical formulae and the third is for involving the experimental data to curve-fitting functions. However, more modern application of the mathematical methodology is to generate techniques that can reproduce the logic of intuitive techniques. They are to provide more objective and comprehensive basis to ideas which are so far

intuitive. That is, the use of the methodology for the analysis of large quantities of data. While this is so, we find that mathematical methodology is used in the synchronic analysis of systems. It refers to the use of structural analysis to test the coherence of a system. The third function of mathematical methodology is to provide facility for experimentation in human and social sciences, in particular. The application of mathematical sciences is on the increase. The primary impetus of increasing interdisciplinary inteaction may attributed to the following factors (16):

1. Technological inducements and availability of sophisticated computers to analyse large mass of data and to simulate the same for the newer information.

2. Generation of data through research or otherwise, which are to be analysed and synthesised objectively to aid prediction.

3. To meet the socio-economic needs and problem-solving needs.

4. Advances in information seeking and collecting procedures (such as Delphi technique, survey analysis, and interview techniques).

5. Institutional factors: Increased teaching of methodology, statistics and mathematics.

6. Social factors: Increasing interest among professional mathematicians in the application of mathematics to a wide variety of fields.

Due to the wide pervasiveness of mathematics we find the emergence of several interdisciplinary subjects (4) such as the following: Librametry, Bibliometries, Engineering statistics, Engineering cybernetics, Biometry, Biocybernetics, Agrometry, Medicometry, Medical Cybernetics, Agricultural cybernetics, Linguametry, Linguistic cybernetics, psychometrics, Psychocybernetics, Educametry, Educational Cybernetics, Statistical geography, Politometrics, Political cybernetics, Econometrics, Economical cybernetics, Sociometry, Sociocybernetics, and Cyberculture.

62 Contribution of Traditonal subjects: Hybridization

The traditional fields such Physics, Chemistry, Biology, Lin-

guistics, Psychology, Economics, Sociology and Law have contributed to hybridisation of subjects leading to a conference of interdisciplinary subjects. Analysing the uses of sociology in problem-focussed research, P F Lazarsfield et al (16) have identified the following aspects:

1. The uses of sociology in the profession: Law, Medicine, Social work and Social Welfare.

2. The uses of sociology in establishments, the military establishment, public administration, political parties, educational establishments, foreign policy, etc.

3. Social problems and formal planning poverty, delinquency, developing social programmes, the school and the family, unemployment, man-power and area-development, public health and agency.

4. Rapid social change: sociology in developing areas and rural sociology.

The sociologist thus brings in his professional expertise, methods of analysis, and techniques in analysing a problem occuring in various spheres of activity. Thus, we find a plethora of sociologies such as sociology of science, sociology of technology, sociobiology, medical sociology, sociolinguistics, social psychology, educational sociology, sociogeography, political sociology, socio-economics, socio-legal studies. Similar development of interdisciplinary subjects are astrophysics, astrochemistry, astrobiology, space physics, physical chemistry, bio-chemistry, bio-physics, biomechanics, biopsychology, geophysics, geo-chemistry, economic geology, medical jurisprudence, biolinguistics, psycholinguistics, educational psychology, political psychology, economic geography, geopolitics, anthropobiology, anthropopsychology and legal psychology.

There are several cases in which the hybridisation has already happened among the already hybridized subjects such as bio-physical chemitry, political-social psychology etc. There can of course be no restrictions for such development. Change is the essence of knowledge growth; and multidisciplinary dynamics is continuous, multidirectional, and multidimensional and inevitable.

63 Clusters and Aggregation

Multidisciplinary research brings into focus the clusters of subjects such as Gandhian studies, Marxism studies, management science, surface sciences, social sciences, environment sciences, area studies, defence sciences, and behavioural science. They bring in segments of studies from different disciplines on a particular focus. These are phases of multidisciplinary subjects ultimately leading to integration and evolution of subjects. Aggregation of subjects such as mathematical sciences, physical sciences, biosciences, medical sciences, language sciences, social sciences are also bring generated as super-structure of disciplinary studies. Initiation of discipline-bonds arise even in subjects such as mathematics for engineers, psychology for nurses. These kinds of subjects emerge due to contextual impetus, chance associations, as well as due to conscious nurturing of multidisciplinary subject developments. It may be stated that for construction of successful strategies of survival, future development of knowledge had to be postulated in unknown disciplines, and in unknown combinations; but none can stop it as knowledge-dynamics goes on as a creative product of the humanity.

7 Modes of formation multidisciplinary subjects

The different ways in which the multidisciplinary subjects have formed can be projected into a typology. From the classifications point-of-view a comprehensive typology has been drawn out. The typology is matched with the one derivable from general systems theory. It was first presented in the Third International Study Conference for Classification Research by Gopinath and Seetharama (11). The Table 2 is a modified version of the same. Such a typology is helpful for the design of classification schemes.

Models from Others:

Kenneth Boulding (5). Two-parented hybrid disciplines — The process of interaction between two known independent disciplines resulting in the emergence of a new discipline.

B M Kedrov (14). *pivotesation,* the process of the permeation of particular natural sciences by more general abstract (mathemati-