THE ROLE OF INFORMATION AND COMMUNICATION SYSTEMS AND SUBSYSTEMS IN CHEMICAL EDUCATION AT THE UNIVERSITY LEVEL

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The progress of any complex endeavour is a function of at least three activities which can be characterized as tradition, diffusion and innovation. In all three the communication and the acts of emission, transmission and absorption of information are the most essential ingredients. These interactions are incorporated in any real system so deeply that sometimes we focus our attention too much on the leaves and forget the roots and connecting links of the complex entity.

In a complex of chemical education at the university level, and, generally in university activities, either undergraduate, graduate, doctoral or postdoctoral, the centre of gravity has moved in quite a revolutionary manner towards the processes and operations of emission, transmission and absorption of knowledge.

Also, in spite of the fact that it is extremely difficult to distinguish the sectors of education, training, research and various services, the rational organizational schemes have to point to the dominant knots in the multidimensional network of the university position in the contemporary society.

Chemistry itself cannot be treated, as it usually is, as a single discipline; it always was, and nowadays is much more, an interdiscipline or multidiscipline. In addition to linguistics, logical relationships, mathematics and physics, the formative components for its status and content include geology, biology, various technologies and very wide applications. Traditional definitions may be helpful only if the whole spectrum of various interactions, including physico-psycho-sociological ones, are put into the right retrospect and prospect.

From this point of view we shall try to present some relationships in which the information, documentation and communication activities are taken as component and distinctive parts of chemical education at the university level.

CULTURE

In our world which in fact becomes more and more common to all mankind, one culture, embracing natural, social and humanistic sciences as well as arts and faiths in their pluralistic and polycentred structures, has to be built-in in any educational system. Instead of emphasizing divisions, specializations and differences, the modern educational approaches have to

respect unity and unifying relationships. Education in general should provide aids and dialogues for translating experience into a more powerful system of notation and ordering. University education is much more a two-way road influencing both the students and professors, and inducing them for a lifelong continual education including learning, on-the-job-training and research. Focusing on one traditional discipline, scientific field, or academic profession means only that some examples for orientation and entering into the complex world are specially chosen. According to behavioural psychologists the prime component of the conscience active in the voluntary control of behaviour is the hierarchy of values of the individual. Only when the mind becomes aware of the stimulus which is of interest for an individual, the learning process proceeds to thinking and storage of the information in memory. The theory of instruction[1] requires 'statements about predisposing conditions for learning, statements about the structure of the body of knowledge, statements about the sequence of material presented, and statements about the quality of rewards, where curiosity seems among the most reliable of motives, and the will to learn is taken as an intrinsic motive, one that finds both its source and its reward in its own exercise'.

The conscious and unconscious organization of various interactions between individual and environment, man and nature, man and man, man and sign, and man and machine, in the form of messages, units of experience, and units of thought, and above all the coherent system for these units, become the most important common ground for unified, simultaneously general and specific exploration of the problems and solutions in contemporary world. In chemistry the needs and responses for such an approach have always been prominent, and therefore we shall try to accentuate some situations in the information field which may be relevant to our theme.

ASPECTS

Between emission and absorption the interaction can be treated either in an extrinsic or intrinsic way; the terms such as operations and processes, active interferences and more or less spontaneous change are, therefore, usually defined as various modes emphasizing the character of possible interventions. In general, duality itself is expressed in a number of ways, e.g. 'know how' and 'know why' or in quite fundamental elementary characterizations as in yes–no code (bits), or + — polarity, etc.

For orientation and systematization we shall frequently distinguish between operations and processes of information transfer. Writing, drawing, printing, coding and various methods, techniques and means of preparing, conducting and presenting reference material and activities, can be taken as operative; the group of processes is represented by the language with its vocabulary, grammar, syntax and semantics, as an instrument of thinking, the numerical system, mathematics, logic and the most essential parts of emission and absorption which are more than simple outputs and inputs. In discussion on various relationships it seems advantageous to differentiate simplexes and complexes, subsystems and systems, and other building blocks from which the real structures are composed.

Both groups, operations and processes, can be organized and to some extent materialized as special patterns. Meanwhile, the potentials and capacities for operational activities can be defined, multiplied and enlarged much more easily. Therefore, the revolutionary periods in history of mankind started or were accompanied by new methods and techniques of operational character, such as writing (about 5 000 years ago) and printing (about 500 years ago); now, a new and comparable period is opening in space and time dimensions of contemporary reprographical and computerized configurations.

There are two measures if we are dealing with 'units of information' which can be identified; one measure is developed by Shannon[2] expressing a physical concept which has no relationship to the meaning that is conveyed by the message, the unit of which is called a 'bit'; the other is conceptual and related to human values through semantic and behavioural considerations; therefore there is a distinction between Shannon's and human communication theory.

METHODS OF APPROACH

Observations, experimentations and systematizations, an old division, are in fact complementary steps in scientific approaches. Usually, observations mean collecting of data or facts by careful registration of definable phenomena, and an answer mainly to the question: what? Experimentation in a systematic manner expresses relationships answering for well-defined systems to the question: how? Closely connected with answers to the questions 'what?' and 'how?' are interpretations giving the elements of theoretical approach and answering to the question: why?

According to Ackoff[3], in human theory of communication, units of information answering to 'what?' can be called inbits (information), those answering to 'how?', hubits (instruction) while those answering to 'why?' are mobits (motivation). 'Any one message may inform, instruct or motivate, or do any combination of these. Information refers to what an individual does, instruction to how he does it, and motivation to why he does it.' *Figure 1* describes these relationships.

In ordinary life, and much more in science, we are frequently asking for answers to three other questions, namely, who, where and when.

Probably, these three sets of the three question–answer relationships can remind us that in our search for a right type of either natural or artificial structure and function, there are quite obvious phases which have to be particularly defined and realized.

LEVELS OF LITERACY AND PRINCIPLES OF SCIENTIFIC WORK

Trying to characterize the potential of one individual or social group, especially with respect to educational and cultural achievements, it seems advantageous to differentiate between various levels of literacy in relation to information performance. In this sense a distinction can be made between literate people according to: (1) their general ability to write and read (elementary literacy); (2) the regular use of writing and reading (everyday

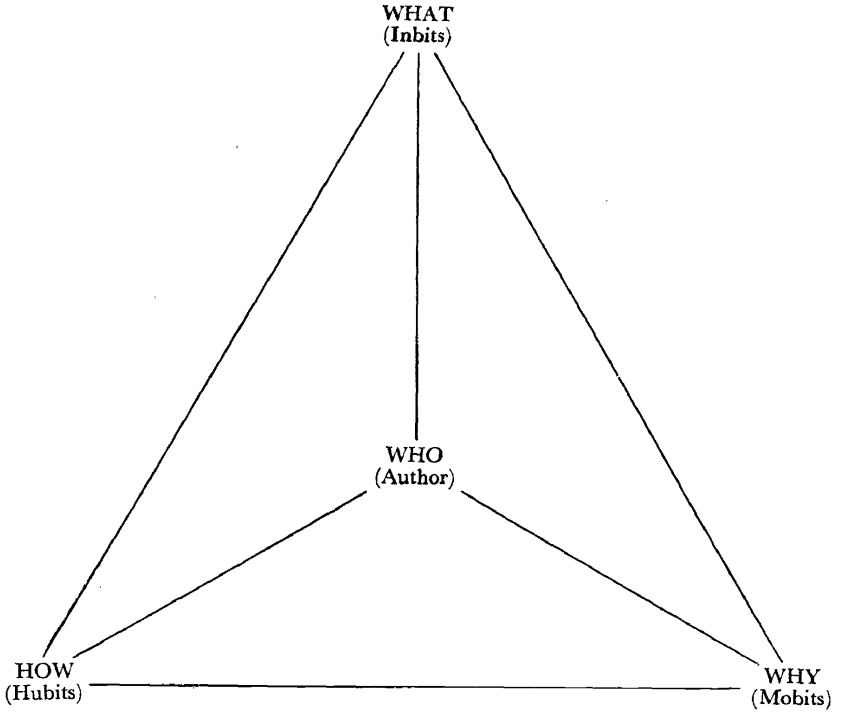


Figure 1. Questions characterizing the content of information.

used literacy); (3) the extended ability and practice to solve the problems by means of wider access to more or less all relevant knowledge (scientific literacy); and (4) the ability either to design, develop or extensively use the systems, methods and techniques for data and information processing (time-extended literacy). Probably, it will not be far from the right value if, to express the corresponding category of literacy, we use the dimensional power of ten, say 10^1, 10^2, 10^3 and 10^4, respectively. *Figure 2* shows characteristic elements of these levels of literacy. Usually the vocational and college or first university degree qualifications do not reach beyond the level of everyday used literacy. The right type of graduate studies and especially the Ph.D. qualification can ensure literacy of the third, and to some extent of the fourth dimensional characteristics. The spreading of fourth dimensional literacy might be the result of the development of 'on-line', 'time-sharing', and 'real-time' data and information processing multisystems.

Concerning the spirit and practice of science, it should be noted that there are at work moral values which enable extensive and intensive integration of knowledge. This morality is mainly based on full acceptance of four principles: (i) the sense of openness, namely, that the results should be available to all interested scientists as soon as possible with a true account of the experimental procedures and theoretical approaches; such an obligation is

0	I	II
Petrographs	Monumental writings & reading	Everyday
Signs Pictures Sculptures	Elementary	
Characterization: Diffuse Dominant:	one-dimensional immediate contact	two-dimensional surface
Numerical (dimensional) expression:		
10^0	10^1	10^2

III	IV	levels (categories)
Scientific	Dynamic (technological)	
three-dimensional space	four-dimensional time	factors
10^3	10^4	

The full use of literacy of higher levels presupposes the full use of all preceding ones.

Figure 2. Development of literacy

performed under (ii) the freedom that no one is forced either to publish or what to publish; the application of both these principles leads to (iii) the responsibility for what is published; while the application and reflection of these three principles result in (iv) the confidence of the scientific community by which the results, which can be verified by everybody, will be accepted.

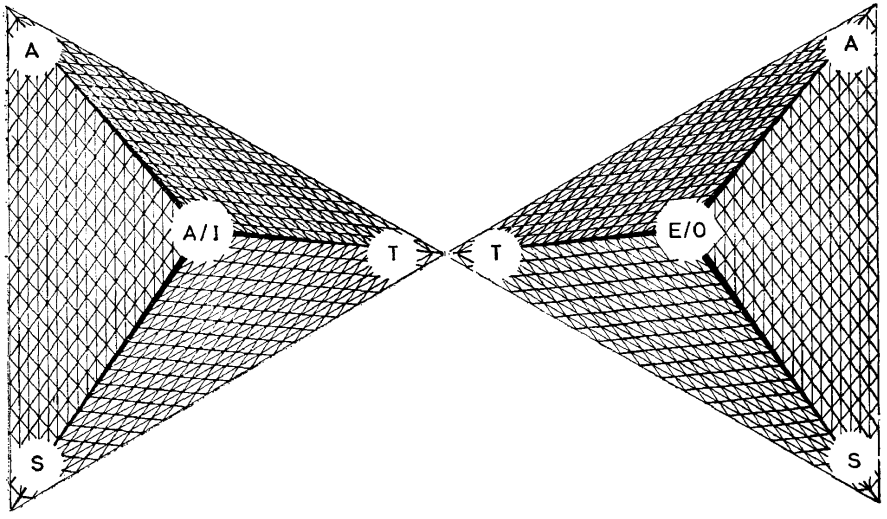
There is quite a real difference in application of these principles according to the character of research. The results of fundamental research are nearly all published; the directed fundamental research is published somewhat less than 100 per cent; applied research is published about ten per cent, and the results of development about one per cent or less.

The costs for performing research and development are rising in our sequence and for orientation the 1:4:10:100 relationships can be used.

All these characteristics have to be taken into account when planning the curricula, and studying and working schemes, as well as research engagements at undergraduate, graduate, doctoral and postdoctoral levels.

COMMUNICATION FUNCTIONS

The communication system is composed of at least five subsystems which only in their working unity may give satisfactory results. These five functions and structures, schematically expressed in *Figures 3* and *4*, can be named according to their dominant activities: (1) the emission; (2) the transmission; (3) the accumulation; (4) the selection; and (5) the absorption. Some of them were mentioned before but the role of interdependent activities of all the five subsystems can never be emphasized too much. Transmission, accumu-



Figures 3 and 4. Five functions of information complex: A/I denotes (Absorption/Input), E/O (Emission/Output), A (Accummulation) and S (Selection).

lation and selection can be called referent to be distinguished from efferent and afferent activities which are unidirectional. Transmission conveys oral, written and printed messages, directly or through various telecommunication media. The accumulating sector represents archives, libraries, bibliographic, documentation and information centres, with a great variety of information storage. The selecting activity was until recently wholly dependent on direct human interventions; nowadays there are quite dramatic changes: selection can be performed with enormous speed and highest accuracy; the same is valid for processing of various mathematical and logical operations. Following the performances of reference functions the potentials and capacities of inputs and outputs are also radically changed. Thus the whole scene has been changed from nearly static and locally limited and separated units to extremely dynamic and very far-reaching information complexes.

CHANNELS

There are some practical consequences of the situation presented in the preceding paragraphs for the individual scientist or professional man, and scientific or professional community.

First of all we have to differentiate between internal and external spheres of activity or information sources, which could be characterized as primary, secondary and tertiary. *Figure 5* shows these relationships. Defining research as conscious activity towards creating new information, the communication channel through which the new elements can be incorporated into the general body of knowledge is called primary. Thus, primary journals, publishing original scientific communications, were, from their appearance 300 years ago, are nowadays, and will be, at least for the near future, the

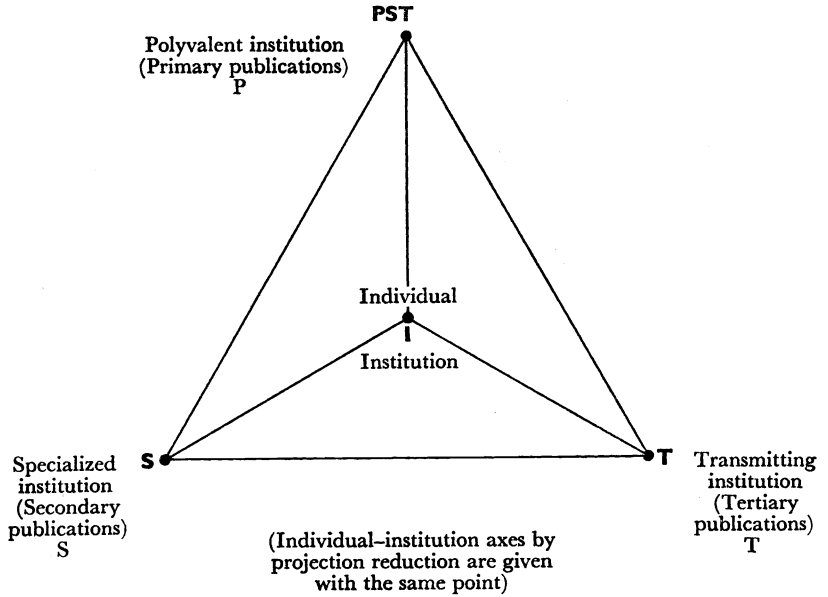


Figure 5. Relationships between institutions and publications of various character

most important vehicle of scientific progress. The secondary publications and documents are compilations, tables, monographs, reviews, and above all abstracts and synopses giving account of material already published in the primary sources. The tertiary sources represent indexes, catalogues and other instruments indicating the channel through which something of interest could be found. In *Figure 6* a corresponding scheme is given.

Although in preparation of all these external primary, secondary and tertiary publications, scientists and professional people were and are playing the most important role, the requirements for preparation of all three kinds of documents have been moved in our days very expressively towards the direct responsibility of editors and authors. Nowadays *A Code of Good Practice for Scientific Publications*, of FID/ICSU/IFLA/ISO/Unesco Liaison Committee[4] together with standardization activities have cleared the way for adopting quite definite steps in education and everyday execution of publication duties on the internal and external sides of primary, secondary and tertiary communication channels. The 'basic documentation card' (BDC), containing the essential elements of secondary and tertiary character, can be the best companion for each primary publication[5].

The organization of these six stages (three internal and three external) can be considered as basic for the full success of all new systems (*Chemical Titles*, *Index Chemicus*, *Science Citation Index*, current awareness information services, access and others).

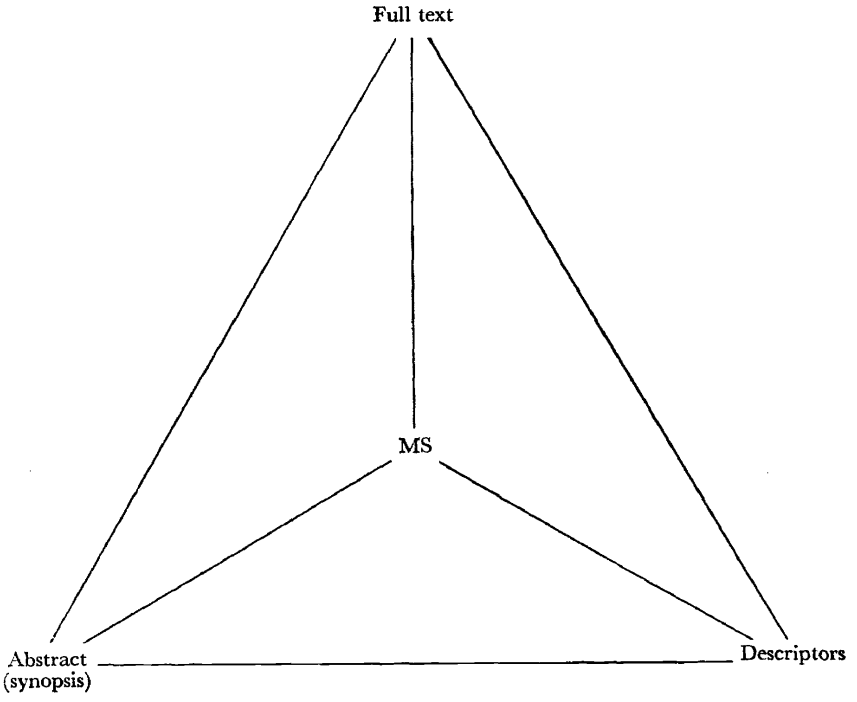


Figure 6. Elements of complete manuscript.

WORKING SCHEMES

From the individual point of view and more or less for every group engaged in complex intellectual tasks, there is usually a need for simple working schemes which might enhance the organization of information. Activities according to such schemes can be performed in part manually, in part with the help of simple appliances, and in part will be best carried out if connected with a large and real world information system[6].

Starting with individual and usually manual notebooks for (1) literature references and extracts, (2) laboratory diary of observations and experiment descriptions, (3) preparative file of specially selected material, one's own and with reference to other sources, and (4) covers for drafts for the emerging manuscript, we have delineated the fundamental four points of information activities, as shown by the scheme in *Figure 7*.

Similar schemes may follow. Sometimes they represent facets in Ranganathan sense, but sometimes they only remind us of the topological simplexes embracing, in the three dimensional models, four elements and five components. The items can be complexes related to: (i) combination of what–how–why and who–where–when; (ii) MS–preprint–publication–reprint; (iii) author–title–place–time; (iv) full text–abstract (synopsis)–reference–index; (v) individuum–group–locality–outside world; (vi) biography–bibliography–locating catalogue–indexing system, etc.

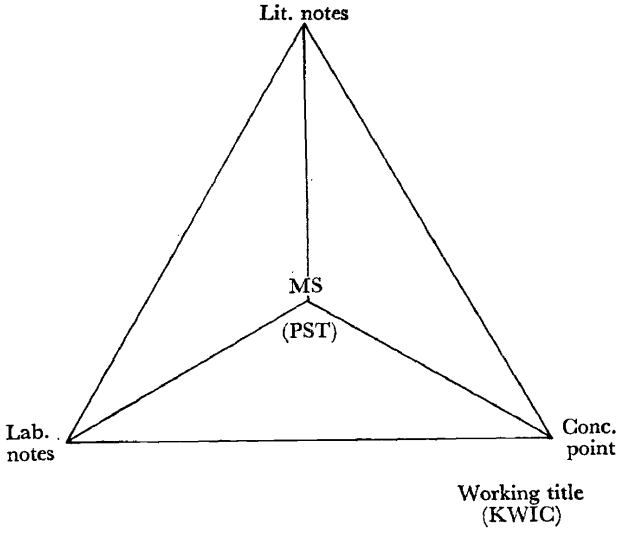


Figure 7. Four points of internal information activities.

In practice conventional and unconventional directories and files, direct and inverse indexes, special microfilm, microfiche, and magnetic tape editions, catalogue sharing, data banks, etc. present real working schemes for a flexible network which although incoherent at present can be taken as an expression of strong forces for building a coherent world information system in the very near future.

UNIVERSITY INFORMATION SYSTEM

In the past, the best university libraries have housed the greater part of the needs of the university population with respect to information functions. However, the production of documents, at least in the final form, has been usually reserved for independent university presses. With the growth of primary publications in the nineteenth and the first half of the twentieth century the centres of activity have been moving towards specialized reference libraries, while serious documentation works have started their independent life quite outside the libraries. The complex: emission–transmission–accumulation–selection–absorption (e–t–a–s–a) has grown spontaneously also outside the libraries, and has been enhanced by new methods and techniques (Medlars, CAS, VINITI, CNRS, ISI, and others). Some coordinative schemes have been developed mainly within the framework of international organizations, and bigger nations. It is interesting that there was no parallel development within the universities. Usually, fragmentation has proceeded much faster than the unifying and coordinating approaches. Meanwhile, the emerging computer and communication centres have accentuated the sharper divisions but at the same time raised hopes in the feasibility of amalgamated systems. It is high time we tried to counterbalance the unbearable pressure in volume and diversification of informa-

tion material, and started the nucleation of the coherent network within the university structure. This network should tentatively embrace: (1) the central library with catalogues and general reference collections; (2) the departmental or special libraries; (3) special documentation centres and groups; (4) telecommunication centres; (5) central processing unit with possibilities for computer-assisted instructions; (6) referral centre; (7) instructional unit for information, documentation and communication activities; (8) facilities for editing and publishing in conventional and unconventional forms.

Some of the units have to function in close connection with lecture rooms, seminars, departmental laboratories and special libraries and information centres, but such collaboration should always enable a free access and extensive use for all interested. This trend has to be pursued very carefully since it nourishes the separation tendencies which are contrary to the spirit not only of the university but of social needs as well. Therefore it would be appropriate to concentrate in one location nearly all previously named units and to instil the spirit of closest collaboration of heterogeneous groups.

LINKS AND ROLES OF REFERRAL CENTRE

Among various organizational structures the most flexible one is probably that of the referral centre which as a distinct unit appeared about five years ago as the National Referral Center for Science and Technology operating in the Library of Congress. It was designed to provide a single place to which everybody may turn for advice on where and how to obtain information on specific topics. The applied concept of 'information resources' is an extremely broad one. It extends to any individual, group, institution or organization with specialized knowledge and the willingness to share this knowledge with others. Following this concept we have established the Referral Centre of the University of Zagreb according to the pattern presented in *Figure 8*.

In order to develop the Referral Centre into a strong concentrated point for information activities an International Permanent Exhibition of Publications (Internacionalna stalna izložba publikacija—ISIP), and Centre for the Study of Librarianship, Documentation and Information Sciences, the latter being an interdepartmental graduate study group, have been included in its framework.

The more complete organizational chart where the information activities are integrated with other functions is shown in *Figure 9*. It is quite obvious that the same construction, completed only by necessary extensions, can perform educational and other functions at the undergraduate level also.

CONCLUDING REMARKS

To counterbalance the specific approaches, we have stressed the general schemes and some inherent aspects of principles, methods, techniques and means, which may be applied to strategy and tactics of the educational system not only in chemistry but also in any other field at the university level.

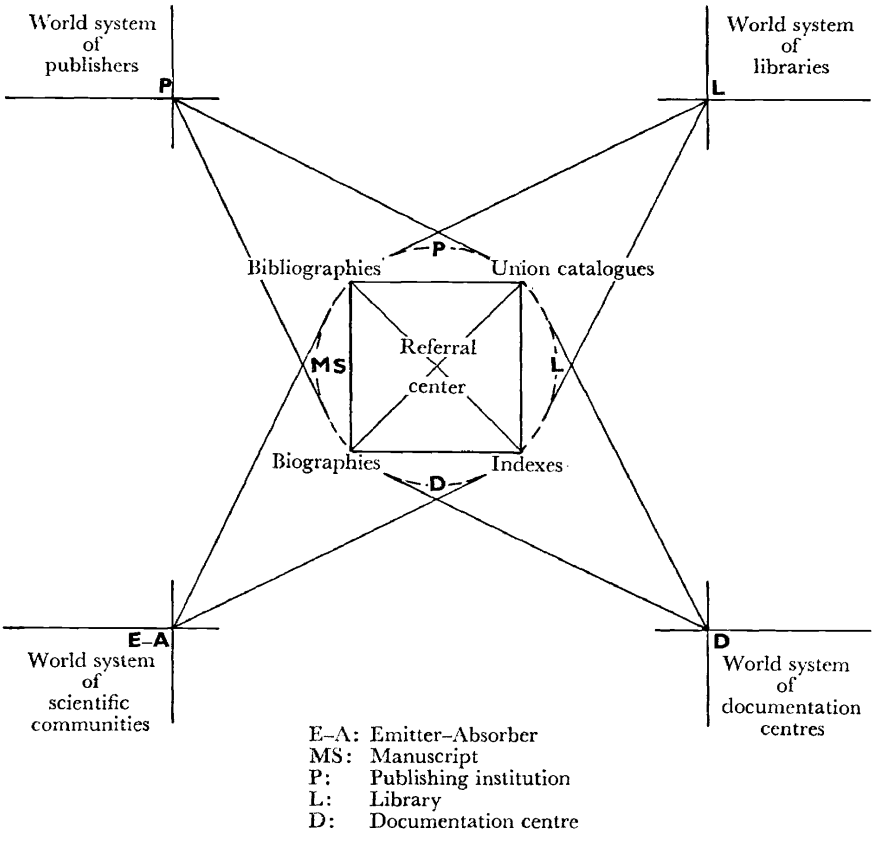


Figure 8. Chain between 'contact points' for information sciences and services

Intentionally more hints were given for building up the chemically oriented subsystem, which in fact represents a very important part of the emerging world information system.

The fundamental position of emission, transmission, accumulation, selection and absorption as a dynamic entity was particularly emphasized.

Many very important questions, such as signs, units, symbols, thesaurus, classification schemes, conceptual approaches, problems of languages, relationships between chemistry and various disciplines, the role of individual, institutional, local, national and international units, problems of semi-publications and publications, and many other very important questions have only been mentioned briefly or not at all.

Probably many items which should be discussed under the title of this contribution will be found under specific headings of much more chemically coloured material. This fact should not obscure the need to go ahead with

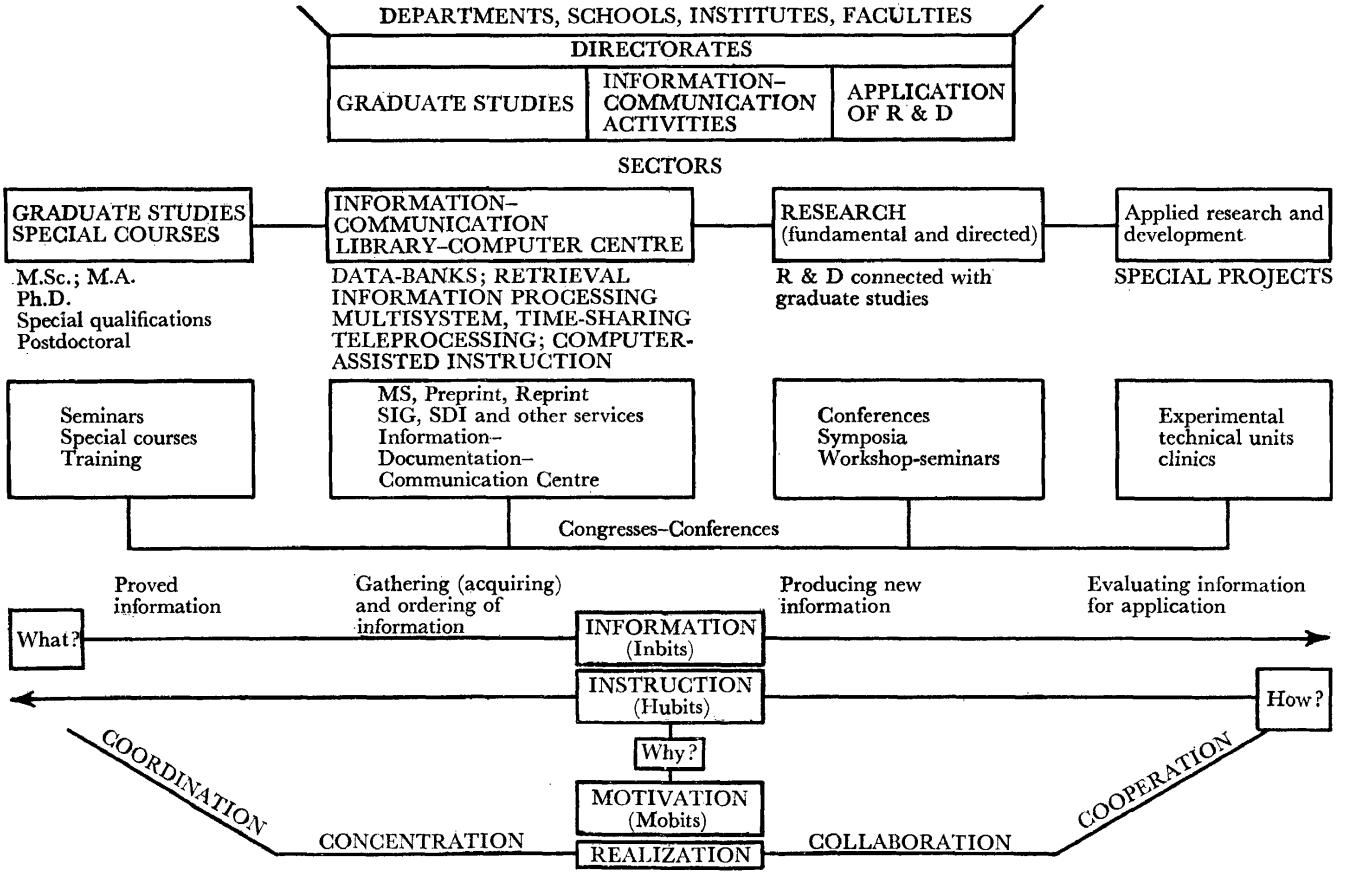


Figure 9. Organizational chart for various university units with essential information activities.

common, very powerful structures, or much more coherent networks of structures, where the connecting attitudes, aptitudes and various channels of communication will be given due priorities.

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