A STRUCTURE OF INFORMATION SCIENCE AND ITS SYSTEMATIZATION
——Experimental Approach and Development through University Education——

By SEIJI OKAYAMA*

1. *Foreword*

My original conception of "Information Science" may be traced directly back to the time when I began to have opportunities to teach physics to those students majoring in non-exact sciences, i.e. humanities, law, economics, etc. Apart from this, I also experienced a period of "groping" for a concept of information science as I tried to formulate an entirely new course named "Fundamentals of Industrial Sciences" in order for effective synthesis of four fields of natural science, i.e. physics, chemistry, biology and geology, to be taught specifically to students of liberal arts.

For about two years from 1967, I was an 'Instructor' in physics at the Awoyama campus of Awoyama Gakuin University in Tokyo, first primarily for students of the Faculty of Literature. It was then that I tried an experimental lecture series on what may be called "Information Physics."

Upon my transfer to Hitotsubashi University in May, 1969, I decided to deepen that experimental approach and, by planning to put it into practice in classroom, eventually to formulate my own system of information science.

My activities thereafter to date may be summarized as follows.

In the year in which I was transferred to Hitotsubashi, I opened a (small-class) seminar titled information science on a voluntary basis. It was a kind of discussion meeting with interested students, held once a week and continued a full year, concerning information, computer and "artificial intelligence." Prior to each discussion period, I selected such documents as would comply with my line of interest and at the same time help my students grasp the general "image" of information science.

In 1970, 'Information Science' was officially included, together with 'Physics,' in the elective junior course curricula in natural sciences for the students of liberal arts.

I took charge of these courses and also a (small-class) seminar. Simultaneously, a similar course called 'Introduction to Data Science' was installed along with the said curricula. Atsushi Shimanuki, an Instructor, who doubles as an Assistant Professor at the Tokyo Gakugei University, has been in charge of this new course at Hitotsubashi.

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It should also be mentioned that 'Fundamental Mathematics,' which is definitely related to computerization of information, has been taught by Prof. Shinji Kataoka of Hitotsubashi.

According to this year's synopsis of curricula, this course is now included as 'Mathematics E.'

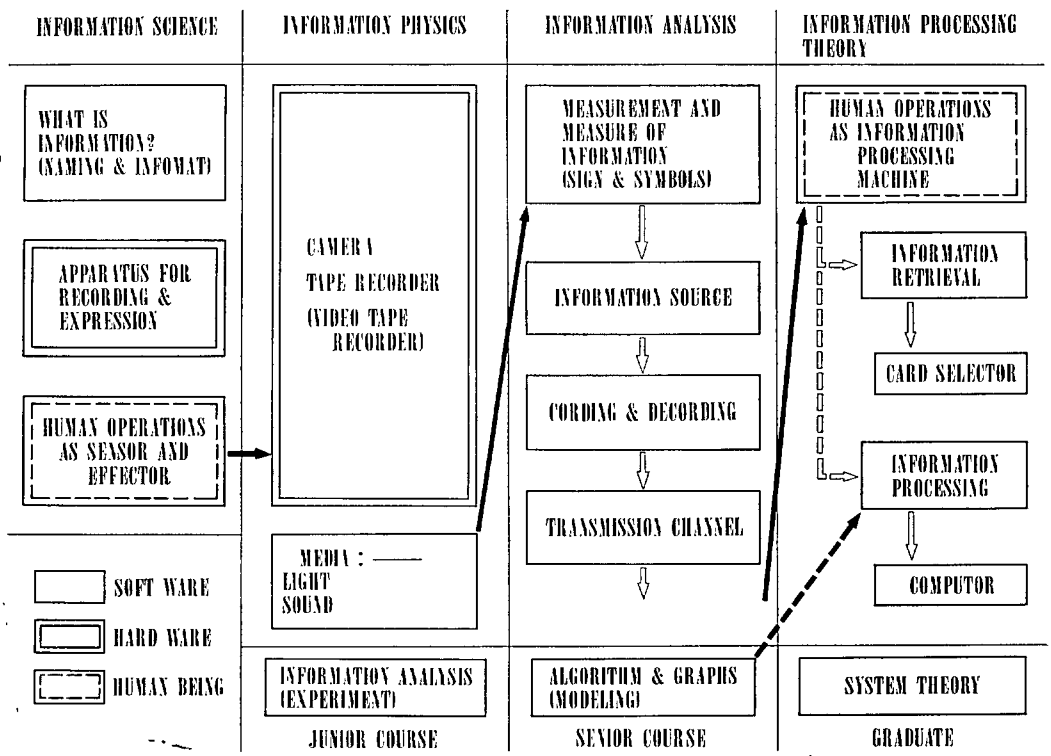
It deserves attention that two new courses, both relating to information science, were thus installed at once in 1970.

Incidentally in the same year, a new course titled 'Information Science' was instituted at Awoyama-Gakuin University, too, and my chair as a visiting Instructor there changed from 'Physics' to this infant curriculum.

Also in 1970, at the graduate school of the Faculty of Economics at Hitotsubashi (the faculty to which I belong), I began to take additional charge of 'Information Processing Theory' and its extention in a seminar class. Since 1971, I have also been in charge of 'Information Analysis' and its seminar class for undergraduates in their senior course each year.

These curricula for senior course undergraduates and for graduate students at the

TABLE 1. A STRUCTURE OF INFORMATION SCIENCE LECTURE AND SEMINAR



Faculty of Economics are categorized in the 'Statistics and Applied Mathematics." This category now includes, in addition, 'Computer Theory' and its seminar extension for senior course undergraduates and 'Special Problems in Cybernetics and Computer' and its seminar version for graudates, all under the guidance of Prof. Kataoka. (This year's synopsis of curricula for graduate students has a lecture course and a seminar class in 'Special Problems in Cybernetics and Computer' by Assistant Prof. Takashi Nagashima, along with Prof. Kataoka's.)

Out of such a background has my present function emerged to teach information science-related subjects (referred to as simply Information Science hereafter) to vertically segmented student groups of junior course undergraduates, second-semester undergraduates and graduate students.

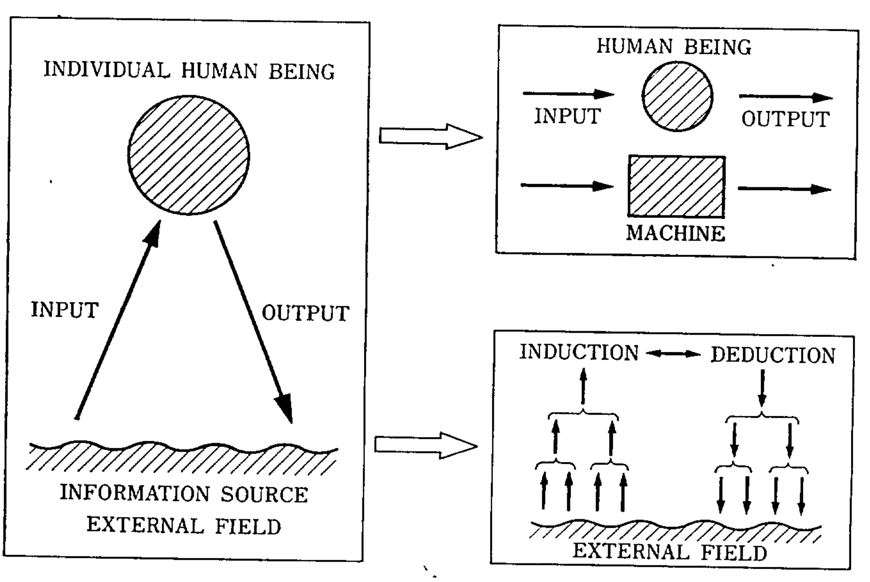
In the meantime, I have gathered on my own such themes and subordinate subjects as I would like to include in Information Science and have paid due efforts to systematize them into a teaching arrangement which would satisfy at least myself.

As to systematization of Information Science, I already made a report last year in which I discussed the matter in its relation to my classroom experiences. This time, therefore, I limit my paper only to its essentials and then to my extra-classroom studies.

1-1 Basic Methods of Information Science

1-1-1 To determine an individual human being to be the (philosophical) subject to treat information. To cover, therefore, all the conceivable forms and channels of information, such as seen in processing and transmission of information (information in its larger sense including natural dialogue), as objects to be studied.

FIG. 1. BASIC METHODS OF INFORMATION SCIENCE



1-1-2 To approach the problem of information processing by comparing the capabilities of man and machinery in the total process from input of information to release of output.

1-1-3 To take up theories for and experiments with quantitative treatment of information and information media, giving equal importance to both theory and experiment. That is, to develop inductive and deductive methods simultaneously.

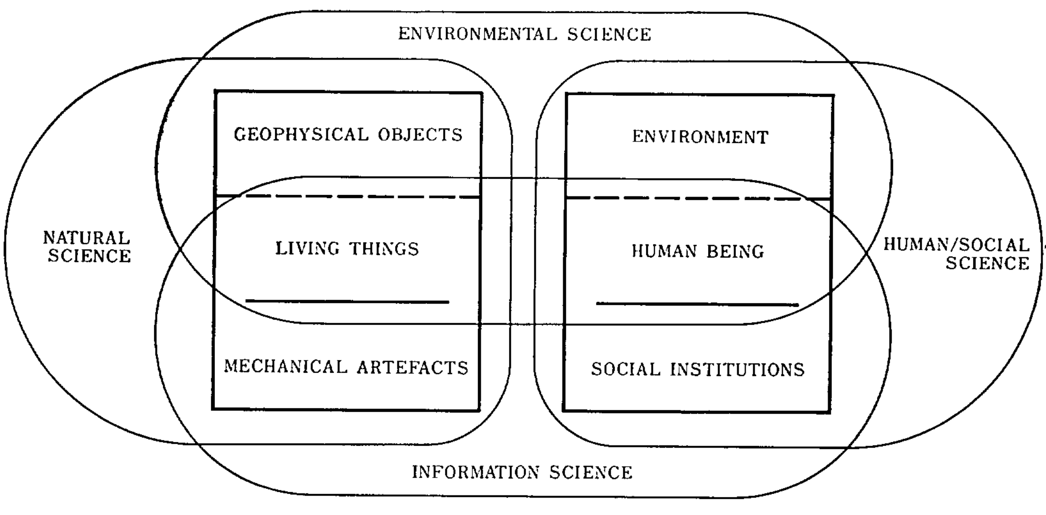
We have confirmed the above-mentioned three points as the methodological bases of our studies.

1-2 Place of Information as a Category of Science

Among the objects of natural science are geophysical objects, living things, and mechanical artefacts. In human / social science, these correspond to environment, human being and social institutions, respectively. This means, in more concrete words, that living things to natural science are what human being is to human / social science; that physical environmental factors such as the earth, air and solar energy that are studied about in natural science correspond in human / social science to human environmental factors, i.e. the other human beings as distinctly existing objects; that development and exploitation of machines and apparatus that are forms of technological application of natural science correspond in human / social science to organized and institutionalized communities, or the society, of human beings.

If these lines of demarcation can be recognized between the objects of natural science and those of human / social science, there emerges an interdisciplinary third category of science, or information science which comprises the objects of the first two categories of

FIG. 2. PLACE OF INFORMATION SCIENCE AS A CATEGORY OF SCIENCE



science (e.g. living things and human beings; physical artefacts and human society) and approaches them by mathematical and quantitative methods and general methodologies employed by natural scientists.

Furthermore, as a development from this third category of science, we can envision a fourth, which may be called environmental science.

1-3 Curricula and Information

Study has been under way at the special committee for improvement of curricula at Hitotsubashi University, in order for a comprehensive reform of its curricula arrangement and eventual realization of totally coherent four-year university education for each student. Reexamining liberal arts courses in the first place, the committee has come out with a package of recommendations in which it sets forth its "basic concept that education in liberal arts should not merely be a preparatory basis on which to proceed to specialized courses."

Although the committee concedes that it is yet difficult to formulate the contents of such a concept, it does specify their basic nature as follows——

(a) Such courses as would be deemed indispensable for all university students, regardless of their specialized fields of studies;

(b) Such courses as would enable each student to understand interdisciplinary relations between his specialized fields and other fields and to comprehend various branches of scholarship in a broad perspective;

(c) Such courses as would lay common bases for all fields of social science.

Information science may be evaluated as a reasonably advanced experimental product, so to speak, of the kind of educational concept stated above.

2. *A Structure of Information Science and General Contents of Curricula*

If we define an individual human being as a "black box" with an information input / output function, we can logically determine the general contents of which courses in information theories and relevant experiments respectively should consist.

Lecture courses in Information Science at Hitotsubashi University continue on a year-round basis for undergraduates and for one semester for graduate students while (small-class) seminars last for a whole two-semester year for both undergraduates and graduates. Lecture series and seminars in Information Science are all elective, but it is compulsory that senior-class students taking a first year seminar course take the same course (on an advanced level) again in their second year. That is, two year seminars are intended to help students with their graduation theses.

Essentials of curricula, such as their general contents and teaching methods, are decided and put into practice in consideration of the class hours and class years (or semesters) explained above.

As for textbooks used in Information Science, my students are given my writing "Expression and Memory" (I & II).

In Information Physics, no particular textbook has been specified.

TABLE 2. A STRUCTURE OF INFORMATION SCIENCE AND THREE PARTS IN CURRICULA

1	INFORMATION INPUT
(1)	EVENTS & ITS NAMING
(2)	MEASUREMENT (A) BY HUMAN SENSOR (B) BY MEASURING INSTRUMENT
(3)	RECORDING (A) MEMORY CHARACTERISTICS (B) CHARACTERISTICS OF RECORDER
2	INFORMATION PROCESSING
(1)	CALLING ON INFORMATION (A) FROM THE MEMORY OF MEN (B) FROM THE STORED EXTERNAL MEMORY
(2)	DEDUCTION (A) BY HUMAN INTELLIGENCE (B) BY INFORMATION PROCESSING MACHINE
(3)	INDUCTION, ANALOGY, ABDUCTION, AND INFERENCE
3	INFORMATION OUTPUT
(1)	EXPRESSION FOR VISUAL SENSATION VISUAL SIGN (A) FROM HUMAN BEINGS (α) LETTER (β) INDICATOR DISPLAY (γ) BODY LANGUAGE (B) FROM VISUAL AIDS..................ENLARGING AND TRANSMISSION FACTOR
(2)	EXPRESSION FOR AUDITORY SENSATION ACOUSTIC SIGN (A) FROM HUMAN BEINGS (α) LANGUAGE (B) FROM AUDIO AIDS..................ENLARGING AND TRANSMISSION FACTOR
(3)	EXPRESSION FOR SENSOR ORGAN EXCEPT AUDIO-VISUAL SENSATION

In Information Analysis and Information Processing Theory, we use as a reference book the "Information Science" which is a joint work by Motoyoshi Suguita, a professor emeritus at Hitotsubashi, and myself.

Also, I supplement my teaching materials with my manuscripts for extracurricular and extramural lectures and my research reports, copies of which I distribute to my students as necessary.

For each actual class hour, I prepare a more concrete subordinate subject.

2-1 Lectures

Because of the essential nature of Information Science, and in order to positively help students learn, we make it a rule to mix for each class hour (1) a lecture period using audiovisuals and (2) an after-lecture exercise. This rule has almost become a fixture in Junior courses.

Lectures with audiovisual aids have been attempted for quite a few years now. At the branch campus of Hitotsubashi where Junior course are persued, some stock of audiovisual ware has been prepared. To make the best use of it, the intramural Committee for Audiovisual Education was started in 1971.

In April, 1971, we also saw on the same branch campus the institution of an audiovisual materials production control office, which has been operated by this Committee with an 'Assistant' regularly attending it. In April, 1974, we compiled a manual for effective use of the materials now stored in this office and distributed copies of the manual to all instructors concerned.

However, our proposal for institution of a new production studio has not yet been approved by the university authorities, and our tangible equipment cannot as yet be said satisfactory.

As for the after-lecture exercise, about 20 minutes of each class hour (100 minutes) is devoted to it. It is a simple drill in which each student is asked to make a brief report (just enough to fill in a sheet of paper) on the subject or the topic discussed during the same class hour. The drill includes no mathematical problems requiring "correct answers." It is solely intended for us to know the degree of their interest in and understanding of the subject and contents of a lecture period just given, and not much importance is given to it as a means of evaluating each students's grades.

It is through my research activities that I work out many of the problems for these drills, which may be classified into the following categories——

(a) Those to make students confirm——and question the reason for——evidence that a conclusion reached through deductive reasoning cannot necessarily be applied to reality;

(b) Those to make students recognize the fact that the common tendency to receive direct audiovisual information without much doubting its veracity is not always justifiable nor appropriate;

(c) Those to train students in working out for themselves methods and technique by which to evaluate symbols, signs, marks, etc. in terms of their readability;

(d) Those to make students re-categorize from unconventional viewpoints objects and phenomena witnessed in the physical world and then put resultant categories in some order;

(e) Those to make students apply theoretical thinking to practical, tangible matters as in devising rational means of using information, e.g. data-carrying envelops and cards;

(f) Those to make students consider, in relation to the basic nature of numerical expression, the kinds of attention they must pay in numerical indication of data and methematical operations.

Because some students apparently mistook the regular exercise for a way of roll-call and began to submit reports which were perfunctory and not original enough, I told them earlier this year to sign their papers with their "pen names" and we have so far stuck to this practice. I promised with them then that I would make it requisite for them to identify themselves on their report papers only when such a need should arise.

Subjects about which students of Information Science and Information Physics are examined do not largely differ from year to year.

2-2 Seminars

There can be various methods to run the seminars for the junior and senior course undergraduates and for graduate students, such as experimental work, exercise series, research assignment, reading-by-turns of foreign language documents, etc., depending on the kinds of courses, the difference from one seminar to another in the number of attending students, the educational concepts held by instructors, etc.

As for the seminars in my charge, the students start, under my guidance, from a concept or a hint that I provide, collect factual information and relevant data, analyse and process thus collected materials, and finally derive from them a conclusion for themselves to report to the class. I wish I could expect them further to hit upon their own concepts and suggest their own problems, but such a creative role seems as yet beyond their average capacity. Although I have been making constant efforts to improve my method of teaching and guidance, I have not been able yet to fully achieve my purpose. I supplement my class, therefore, with reading of a textbook by turns. There were times when I arranged discussions concerning scientific thoughts and histories of scientific technologies, but students' opinions could not always be expected to engage with one another.

It is my present belief that, after all, the most educational method is rather to make the students interprete and theorize concrete materials and, in so doing, associate them with scientific thoughts and philosophy.

To facilitate experimental work, our research laboratory has been furnished with more equipment each year, which is, however, not yet quite sufficient.

The "extra-class seminars" are intended for third-semester students in general. For each session of this kind which lasts for a few days during the summer vacation season, a textbook to be used is selected and its resumé introduced in advance and then interested students voluntarily apply for participation. Participants "camp out" at retreat facilities, e.g. the Hachioji Seminar House (in western Tokyo) for my seminar. Because the participants in this specific session include those who take no regular course in Information Science, our discussions require my frequent explanation on thoughts and philosophies involved in Information Science. In practice, each student is given an advance assignment to read a specific chapter of the textbook selected and prepare its summary for himself to report at the session. The actual session, then, is carried out through question-and-answer periods concerning such reports by its participants.

Because the number of participants in my seminar is limited to only several each season, their discussions and opinions dig into quite a profound level, and this becomes a unique experience not obtainable in regular lectures or exercises.

The textbooks used in the past extra-class seminars include the "Future Shock" by Alvin Touffler and "Beyond Freedom and Dignity" by B.F. Skinner, both in Japanese translation.

3. *Information Science and Research Activities*

As my chair of Information Science extends from lecture series to exercise sessions to seminar courses, it approximates and even partially overlaps my research activities.

In other words, the substance of activities by each of these distinct teaching methods develops in close interrelation among these methods, eventually to "see the light of day" partly in education and partly in research work. Admittedly, it is often the case that such a development fails to materialize, with the whole process of it ending up in idle thinking or on try-and-err levels.

The following are some fileds of study that I think belong to information science and in which I have reached a certain level of achievement. Each of these fields will be introduced with an explanatory title, and the contents of introduction refer only to those not mentioned above.

3-1 Transition and progress of "Expression and Memory"——A theme essential to conception of systematized information science

The textbook titled Information Science that I specify for my class is one that I compiled from a series of two-page articles which I had contributed under the same title to a specialized magazine and which I later revised and enlarged.

The uniqueness of this text may be surmised from the fact that, at the time of its publication, the National Diet Library inquired of us about the category to which it should belong. It is now out of print but because its reference value still remains, I recently recompiled it into a format of reference text.

At about the same time, or this past April, I started contributing to the aforementioned magazine a new series of articles, titled "Expression and Memory: Revised Edition" and which is to be continued for a year. Each part of the series consists of five successive pages, the first page containing the outline of the contents to follow and the remaining four pages devoted to itemized expositions. With illustrations and photographs inserted therein, it represents a major effort on my part.

3-2 Interdisciplinary topics covering natural, social and human sciences as viewed from standpoint of information science

A publishing company sponsored a regular monthly meeting of five university instructors (specialized in research and teaching in varied fields of natural science) including myself and occasionally with the attendance of a guest participant, in which the group selected diverse subjects of their common interest and held a free discussion to traverse these subjects from whatever angle they happened to choose.

The contents of problems suggested and discussion held in these meetings were written down jointly by the regular members, regardless of their disparate fields of specialization, for publication in the said magazine each month. This serial later was compiled into an independent volume titled "Pandora's Box" after the name of the meeting itself. There were five themes assigned to me to report on, i.e. "Qualitative and quantitative analyses," "On being scientific," "Evolution," "Hypothetical Model," and "Action," all of which I discussed from the viewpoint of information science.

3-3 Description of "computerized society" as visualized through recognition of present state of development and "fear of the unknown future"

Machinery has been welcomed as a means of replacing, reinforcing and enlarging man's capacities to function and act, but can it be unconditionally accepted? To answer this question, I had a 16mm film (titled "Man-made Brain") produced with myself participating in its production process from planning and collection of materials to appearance in an interview filmed and editing of the film. As for its contents, we therein introduced instances of the latest development toward a "computerized society" such as ETL robot, automatic diagnoses of diseases, "illustromat" for automatic drawing of stereograms, CVS for unmanned personal transit en masse, fingerprints identification and production of works of art by use of computers, Japan's biggest data transmitting system, etc. In so doing, we also warned the audience of anxieties likely to be caused in such a futuristic society, by putting in narration describing aged people troubled by complex automatic vending machines or the plight of those men dropping out of such a society because of their inability to adapt themselves to machinery's command.

3-4 Machinery's definite influence upon man on machine-to-man interface

Man not only lives by responding physiologically or physically to his outer world, as by use of senses and bodily actions. He also lives in trying to be a "better" entity as a spiritual and social existence on his interface with the social system, or in trying to grow as a human being.

Machinery must be designed to meet the needs of man, but even thus designed machinery counteracts him by forcing him to adapt himself to machinery. This is a definite problem to man living in a "man-made" world. By comparing natural dialogue and telephone communications, or an over-the-counter sales clerk and an automatic vending machine, we considered such problems as the inevitable pressure of machinery's existence on human beings, and influences of mechanization (which should represent improvements in a sub-system of the society) upon the total system of the society.

3-5 Development of a basic theory for quantitative measurement of information, and proposal of a special guage with binary-scale indication

Reception and release of numerical information by a human being depends on the decimal system whereas computers use the binary system. But in applying the quantitative definition of information to measurement, we reasoned that the binary scale should rather be the fundamental mathematical order in which to conduct qualitative analyses and quantitative expression of the properties of an item measured. If we were to define measurement as a procedure to give numerical expression according to a certain rule, and if we were to confirm that measurement is completed with measuring operation plus indication of the result of measurement, it followed that the elementary method of such operations is partition and, therefore, that basically their results should be expressed by use of binary system. In this relation, we explained a method to measure by binary scale the basic quantity of length, mass and time.

We also worked out and introduced to interested sources an experimental model of a binary block gauge to implement our teaching as to this specific method.

3-6 Form of indication for measuring instrument developed from viewpoint of information science rather than that of human engineering

Ordinarily, the indication of a measuring instrument has a rectilinear scale, which is an application of physics as laws of motion. But to the user of a measuring instrument, or man himself, stimuli to his senses occur logarithmically, and only two to three significant figures suffice to express whatever quantity he must study in his day-to-day life. There *are* calculation scales suited to this familiar level of exactitude, but there is no indication similar to this for measuring tools.

By way of trial, I created a logarithmic scale and made my students use it and learn from experience the convenience of such a scale.

Generally speaking, the indication of a measuring instrument should go beyond mere presentation of values measured. It had better be in such a form as will help its user intuitively perceive what information he originally wanted. To exemplify such a tool, I suggested an improved scale.

3-7 A hand-made "toy" computer with which to operate algorithms to win games

Learning how to maintain and operate information processing machines is only secondary in importance to understanding of the procedures involved in information processing. Difficult software programming can be taught more interestingly and more efficiently by use of simple "hard" teaching aids.

To demonstrate this, I created a toy computer with which to play Nim games. During the annual intramural cultural exposition in autumn, 1968 (the Hitotsubashi Festival), I prepared one which could handle five lots of 15 unit pieces each, and taught its use and operation to kindergarten children to play the game with adult visitors to the festival. Play they did, and won. This toy machine was a digital system, but I also made an analogue style variation to play Wythoff games. These are, in a word, tools to perform algorithmic procedures without calculation with figures.

3-8 Quality and abilities required of assistants to work for Information Science research offices

Our research offices cannot be negligent of selection of assistants because continuation and facility of research and classroom education largely depend upon their functions. In my case, or in the case of Information Science, person neither a major in natural sciences nor a graduate in human / social sciences can fully satisfy our requirements. To be questioned about an assistant's quality may not so much his specialized field as his basic qualifications in relation to framework of thinking, pattern of handling information and tendency in systematization of information. In fact, these standards of qualification may as well be applied also to assistants for classes in physical and engineering sciences and secretaries in administrative departments. They are, in short, expected to have "information-scientific" learning and technique. I have elsewhere emphasized the matter to this effect by prescribing a list of requirements to be filled by our assistants.

3-9 Others

(a) Researcher as a "consultant"

As mentioned above, the scope of my scholarstic concerns is such that I frequently run into varying requests for consultation, if not for special surveys or research work.

For example, there were such requests from among those graduates who had learned in my classes that thinking and action based on "information-scientific" standpoint would become an essential requirement of life in the future society. Among them were one who planned to initiate a drastically new "mini-school" entirely different from the conventional private preparatory schools, and one who planned a "game plaza" for youths and adults where they could acquire, through playing games, a scientific thinking habit. The idea of the latter was put into practical use even in the designing of pavilions at the 1970 Osaka World Exposition.

Puzzles, games, and similar kinds of pastime may be conducive to people's quest for "revival of humanity" because, unlike public gambling or mass leisure-time activities that enforce rather collective action, these enable the player to play individually.

(b) Day-to-day collection of research materials

It gives us significant clues to conception and pursuit of research themes to store and compile in audiovisual memory such materials as we can gather on a day-to-day basis either first hand or through mass communications media, e.g. newspapers and magazines, and "mini-communications" sources, e.g. specially prepared data and factual reports. This represents my basic posture toward research work. It has also an advantage that by feeding thus collected information into classroom education, we can always add something refreshingly new to its contents, helping both the instructor and the students escape boredom.

For each contemporary individual constantly faced with a "flood" of information, it is crucially important to receive information selectively, and the very starting point of the study of information science lies just there. This I already said but it cannot be overly emphasized. It is not too much to say that it depends on this very point——how to collect research materials selectively——whether systematization of information science can develop to the stage of general recognition.

4. *Conclusion*

So far, I have introduced the gist of all areas of my educational and research activities in Information Science and also traced back the development of a case (admittedly private, though) of systematization of information science. Systematization of information science is, however, too numerous a task for any researcher to attempt singlehandedly, considering the expanse of scholarship required and the diversity of activities necessarily involved.

In developing a system of information science, I have, of course, been getting cooperation from assistants in my research office and the audiovisual materials control office. Also, regular students and extra-class participants in my lecture courses and seminars have been of help to me, through work in the classroom, in various respects.

It is only natural that my classes have been alive with an air of activity not felt in the course of teaching an established set of knowledge. Originally, fundamentally, education and research should thus supplement each other. I am therefore opposed to the recent trend toward functional separation of these two aspects of scholarship.

In develping a system of information science, it goes without saying that I intend a step-by-step progress by keeping close contacts with researchers, educators and others concerned. Particularly important among them are young students of information science whose participation and support I believe are indispensable for its development.

It is in this belief of mine that I close this thesis by emphasizing the "openness" of the study of information science to all interested people, all places and all occasions, intramural or extra.