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RESEARCH AND DEVELOPMENT OF SCIENCE EDUCATION AND MULTIMEDIA MATERIALS IN THE JAPANESE EDUCATION CONTEXT

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In Japan research and development of education use of multimedia started in 1988, with the "Development of New Media Materials Project" initiated and sponsored by the Ministry if Education, Science, Sports and Culture (MESSC) in collaboration with the Japan Audiovisual Education Association. This Project has been promoted for three years and focused on the hypermedia rather than multimedia. Three years of hypermedia studies produced several multimedia software, such as the "Bunkyo Museum" and the "Hyper Science Cube", which emphasised one of the fundamental concepts of hypermedia which is, it should be "non-structured" or it should be "highly flexible-structured". In addition, with a high definition television programme by NHK, "Hypermedia: People and Forest" has been developed, and in 1991 the Ministry of Education recognised hypermedia and multimedia as one concept and enforced the continuation of the project for another three years. During this time, new materials such as the "Hyper Science Cube II" and "Hyper Science: Weather Information" were produced and evaluated. This paper focused on the measures and policies carried out by the Japanese Government and its related authorities, for multimedia in science education in lower secondary schools. Special emphasis to the outstanding features of multimedia is considered to promote future science education in the Japanese education context.

INTRODUCTION

Progress of New Information Technologies

In recent years, micro processing units (MPUs) became high-speed and smaller but with larger capacities, while technologies such as liquid crystal displays (LCDs) and CD-ROMs are identified as emerging technologies. These computer-related technologies have contributed to the standardization in the compression and the representation of various kinds of information, and then the database and interface technologies entered Japanese society as well as the world.

New information technologies integrate several current media such as 16 mm films, video tape recorders, still-cameras, Computer Discs (CD), Liquid Crystal Displays (LCDs) and slides to give us new alternatives for exchanging information. The advent of so-called multimedia, which is characterised by stronger interactivity, has served as a driving force for school reform as well as for the improvement in daily life in the economic, social and cultural development of the nation.

Recently, in addition to multimedia developments, newer telecommunication technologies represented by the Internet with high quality database additions give us global communication facilities.

It is expected that the new types of personal computers and the information and telecommunication systems based on the new information technologies will give us more flexible and open-ended learning environments.

Multimedia Personal Computers

Compared to the past personal computers (PCs), multimedia personal computers (MMPCs) are marked by such features as having CD-ROMs of 640 MB in capacity, and with high quality audiovisual capability. According to the "standard of MMPC version 2.0", announced in May 1993, the basic features of MMPC are as follows: (i) resolution of display–640 x 480–VGA; (ii) CPU–486SX (25MHz), 4MB or a larger capacity for its memory, and 640 MB or a larger capacity for the hard-disk, (iii) CD-ROM drive–built-in double-speed, and (iv) 8-bits digital audio and MIDI capacities.

Since then, because of the competitive development MPUs, all of these features are changing into newer ones in terms of higher speed and bigger capacities. On the other hand based on the report entitled "Promoting Audiovisual Education Utilizing New Education Media (Report)" by the Ministry of Education Japan in March 1992, the term "hypermedia" is defined as a unified device with the use of computers that processes texts, sounds and images and turns them into audiovisual materials.

The adoption of this definition can be appreciated in the materials created during the project "Development of New Media Materials," conducted by the Ministry of Education in 1988. The importance of utilising expensive instruments–computers, compact disks, and videodisks–to gather and process audiovisual information for education purposes is still considered. In other words multimedia, in general, contain a vast bulk of high quality information compiled in the node of the network with the links, and are characterised by "non-linearity."

In this way the users of multimedia have stronger interactivity with such systems or with information in the nodes to retrieve, browse and customize according to their own ideas and interests. Users interact with multimedia as they may wish, which enable them to learn by themselves and change their way of thinking or to transform their cognitive structures by expanding their worlds of thinking activities. In addition to this since the learning process by the users is compiled in the system, the multimedia can be considered as one of the effective media that makes education more scientific, and which promotes education with an application of various audiovisual media. In this way, multimedia include design technology and control technology with modeling, which should be considered as key issues when we think about information education at all school levels as well as that for tertiary education.

CURRENT TRENDS OF EDUCATION WITH SPECIAL EMPHASIS ON MULTIMEDIA IN JAPAN

In 1985, the National Council on Education Reform was established under the direction of the Prime Minister. The establishment of such a Council had not occurred in 30 years since the Japanese Education Reform Committee was dissolved in 1952. In a series of reports made by the Council, the need to reform education in order to be able to deal with the shift to an information-oriented society was pointed out. It was reflected in the revised *Course of Studies* of 1989 in the form of 'Information Education.'

Consequently, the Ministry of Education, Science, Sports and Culture, Japan has been developing policies to deal with the shift toward an information-oriented society. These policies include the following focal points:

1. Fostering information literacy, including the ability to obtain desired information from the vast abundance of information available and to use this information efficiently;
2. Applying new information media in education, science, culture and sports;
3. Developing highly skilled technical personnel to lead the shift to an information-oriented society; and
4. Adapting education facilities to the shift to an information-orientated society and developing information networks.

The Ministry of Education is not the only government sector striving to accelerate the shift towards, an information-oriented society. The Ministry of Post and Telecommunications (MPT) and the Ministry of International Trade and Industry (MITI) are also making efforts to establish a fiber-optic communications network, which will link schools, libraries and other facilities throughout Japan.

In 1989 the Ministry of Education, Science, Sports and Culture, Japan announced the on-going School *Course of Studies*, which is characterised by the promotion of the "New View of Learning Ability" that includes the ability to present ideas, the ability to link and the ability to judge by students' themselves. The concept underlying that *Course of Studies* is also strengthened in the latest version of *Course of Studies* (1998) published at the end of 1998 and at the beginning of 1999, which will be partly effective in April 2000. The key concept here is the spirit to live well in an uncertain 21st Century.

With regards to information literacy education, the 15th Central Council for Education recommended in July 1996 the following key issues, which still exist at the highest priority level in the education reform in Japan: (i) a systematic implementation of information education, (ii) a quality improvement of school education with utilizing information and communication network, (iii) an establishment of a 'New School' coping with highly information–and communication-oriented society, and (iv) a promotion of information morals and fostering human beings as considering the weaker aspects of an information-oriented society such as less attention of copyright and privacy issues, less contact of human beings and less direct experiences among the students.

In May 1997 an 'Action Plan for Revolution and Creation in Economical Structure' prepared by the Education Minister's Secretary, was opened to the public for recommendation on the utilisation of multimedia and information networks.

In August 1997 the revised edition of the 'Education Reform Programme' by the Ministry of Education, Science, Sports and Culture, emphasised the systematic implementation of computers and software into schools and the utilisation of the Internet in schools throughout Japan.

In April 1998, the third edition of the 'Education Reform Programme' pointed out the following issues for primary and secondary education: (i) further utilisation of computers in the primary, lower secondary and upper secondary schools; (ii) compulsory basis contents of information education in home-economics in the lower secondary schools; (iii) creation of new subjects on information education in upper secondary schools; (iv) further securing of educational computers in schools; (v) development and securing of educational software; (vi) systematic securing of information and communication networks in schools; (vii) securing of educational centres as main bases of regional networks in schools; (viii) promotion of research in utilising the Internet and its related fields; (ix) promotion of cooperation in several pilot projects carried out by private as well as public sectors; (x) development of pre-service teacher education curricula for information education; (xi) promotion of leadership among teachers coping with the progress of an information-oriented society; and (xii) securing of a national education centre for providing comprehensive information on education and culture, while also providing for the utilisation of multimedia at higher education levels. This should have (i) the promotion of an university network utilising a satellite; (ii) research and development of education contents and methods using multimedia and providing higher education institutions with its results; and (iii) further utilisation of multimedia in higher education institutions.

In this way, as mentioned earlier, especially at the primary and secondary levels of education, new courses of studies have been published with several kinds of information education subjects.

With regard to the change of ideas underlying the new approach to teaching and learning, Table 1 illustrates a general scheme world-wide, under which both constructivism and situated learning could be easily thought of, though it is not published in Japan but being used in the UK.

Table 1
A 'New Curriculum' – New Developments in Teaching and Learning

Viewpoint	**Until 1990's**	**'New' Learning**
Approach	Emphasis on Content	Process-oriented
Focus	Teacher-centered	Learner-centered
Role of Teacher	Expert	Supporter, guide
Emphasis	What to know?	How?
Learning activities	Individual	Group
Mental Posture	Competitive spirit	Collaboration
Role of Learner	Passive	Active
Task	Premediated	Adaptive
Topic	Forced	Deliberation
Error	Failure	Accepted, learn form errors

EDUCATIONAL MEANING OF MULTIMEDIA

Specification of Multimedia

The concept of hypermedia or even multimedia was introduced by V. Bush in his thesis of 1945. However, it was not until some years ago that computers have made it possible to incorporate multimedia into education. Since then, several reports have been written on the development and the evaluation of educational material, installation and development of an interface that integrates different kinds of media, non-structured and non-linear information processing, and validation of the use of different styles of programmes and lessons.

The educational meaning of multimedia can be specified as follows:

1. Convenience in the way of accumulating and utilising information;
2. An instrument for emitting thoughts or divergent thinking skills;
3. Applicability of individualised or personalised lessons;
4. Clarifying the approach to the educational process.

Lessons using multimedia are expected not just as a "Trait-Treatment-Task Interaction (TTTI)," but as a more complicated transformation that involves: learners, learning subject, learning material, and the application of the learning process or lessons. To develop, theoretically and empirically, these four factors of transformation the following research themes can be proposed:

1. Various themes of study on hypermedia.
2. Composition of hyperdocuments.
3. Navigation.
4. Application of methods.
5. Results of hypermedia studies.
6. Hypermedia literacy.

This means that the non-structured characteristics of hypermedia allow for a "Trait-Treatment-Task-Interaction (TTTI)", and an expanded and customised information according to the students' likes and feelings underlying the idea, social constructivism and situated learning. Students reorganize the information in a creative and personal way by editing it as something of their own. The tendency has been to prioritize multimedia ability to make improving changes and to accelerate the development and use of multimedia material in schools realised by the MMPC, which is, in this connection, identified with a unified form of "TV with the telephone and a high quality audio system."

Development of Multimedia

There are two theories of the development of multimedia. One prioritizes the origin and principal characteristic of a non-structured material and system, while the other refers to computer-assisted instruction (CAI) with the addition of images and sounds.

In CAI, teachers define the goals to be achieved and the students help themselves with textual, audible, and visual information. Consequently, multimedia is delivered to let students establish their own goals and to search and choose from a vast variety of information depending on their needs and interests.

Basically, the introduction of multimedia in education started in Japan in 1988 with the financial support from the Ministry of Education, Science, Sports and Culture. The first multimedia materials were "Bunkyo Museum" (1989) and "Hyper Science Cube" (1990). These experiences were collected and further developed in subsequent materials: "Hyper Science Cube II" (1991), "Inoshishi-Kegaji: Life of Shoeki Ando" (1992), "Manual for the Utilisation of Hypermedia", "Hyperscience: Weather Information" and "Japanese Language Education: Shopping in Hypertown" (1993).

These multimedia or hypermedia materials are expected to change educational theories, the utilisation of materials, and the application of development methods. Consequently many other institutions and interest groups have been producing programmes to accelerate the introduction of multimedia and hypermedia in education.

CURRENT TRENDS OF SCIENCE EDUCATION WITH SPECIAL EMPHASIS ON COMPUTERS AND INFORMATION TECHNOLOGIES

The Ministry of Education Japan issued a revised *Course of Studies* in December 1998. For lower secondary schools, measures have been provided to facilitate the transition on the new curriculum, which will be implemented starting from the 2002 school academic year.

Serving as the standard framework for the educational curriculum, the Course of Study has been revised approximately at an interval of every ten years. Since the latest revision is to be enforced in 2001, it will form the basis of the education that is offered at the beginning of the 21st century.

This recent revision of the *Course of Studies* is based on a report submitted to the Ministry of Education by the Education Curriculum Council Japan in 1987 and 1997. The fundamental principle underlying the *Course of Studies* is to develop the foundations for lifelong learning, taking into account the transformation of students' lifestyles and awareness, that will likely occur in conjunction with changes in society in the coming years. The basic aim of the *Course of Studies* is to foster the development of sensitive, well-rounded individuals who will be capable of coping with changes in society by themselves in the 21st century.

The main features of the latest revision can be summed up in the following four points:

1. Improvement of education for the mind.
2. Emphasis on the basics and fundamentals and encouragement of personalised education.
3. Development of self-education capability.
4. Fostering of respect for the cultures and traditions of other countries and of better international understanding.

Several years ago the Ministry of Education Japan surveyed the way in which the current curriculum was being implemented and obtained a great deal of objective data on many different aspects of the present system. The International Education Association (IEA) has also conducted surveys on science education around the world. The results of its second survey presented an international comparison of education in different countries. The survey results indicated the areas where science education in Japan were outstanding as well deficient.

One observation that has been made on the basis of these different analyses of science education in upper secondary schools in Japan today is that science instruction is not being carried out from the standpoint of learning directly from natural things and phenomena. Instead, there is a tendency of instruction to be conducted as a one-way transmission of knowledge from the teacher to the students. As a result, students invariably tend to rely excessively on a passive form of learning and they are not necessarily acquiring the ability to investigate nature through self-initiated inquiries into natural phenomena nor are they developing a positive attitude toward the study of nature.

Formal school education is strongly expected to cultivate abilities for coping adequately with changes in society, including the ongoing progress of science and technology and the advance of information technology. This is just one reason why steps should be taken to improve and upgrade the substance of education along with the teaching and learning methods that are used. In the area of science education, the aim should be to foster the development of scientific thought, judgement and power of expression. This can be accomplished by cultivating a desire for self-education and by motivating students to undertake self-initiated activities to study and investigate natural things and phenomena.

In connection with the latest revision of the contents of science education in lower secondary schools, it has been pointed out that more attention should be paid to their relationship between nature and students' everyday life and things in their immediate surroundings; further, there is a need to foster a stronger interest in intellectual excitations or keeness over and curiosity about natural things and phenomena. One aspect of this observation is that this viewpoint should be specifically incorporated into the improvements made to the contents of the *Course of Studies.* Another important aspect is that teaching students about the relationship between nature and their everyday lives should promote a better understanding of natural phenomena. This will help to improve their understanding of abstract and difficult-to-understand scientific facts when they are presented in the classroom.

With regard to the principles underlying the revision of lower secondary school science education, the following points can be emphasised:

1. Natural things and phenomena are treated in terms of the traditional disciplines of chemistry, physics, biology and physical geography. The contents of science education have been organised by taking into account such factors as the stages of development of students, their aptitude for learning, and the consistency of instruction at each educational level.
2. Greater attention is paid to the selection, consolidation and organization of the contents of the *Course of Studies* based on the so-called constructivism and situated learning advocated. This is done to foster the development of science perspectives and powers of thought by providing sufficient latitude for investigating nature through direct personal experience in the form of observation and experiments.

Compared with the present *Course of Studies,* Subsection 3 of the revision concerning "Treatment of Contents" contains a much more detailed description on the scope of subject material to be presented. This step was taken to prevent the contents of textbooks from becoming overly complicated or a mere arrangement of wide-ranging factual information. In the case of a substantive subject like science, textbooks are apt to contain detailed factual descriptions rather than explanations of the methods used in studying nature through observation and experiments. Thus, there is a tendency for instruction to become a one-way transmission of this factual knowledge by the teacher and passive memorisation by the students. The "Treatment of Contents" has been described in detail to avoid this type of instruction.

3. Instruction should not be conducted through an over-reliance on the transmission of factual information; rather, it should foster the development of the students' abilities and desire to pursue solutions to problems enthusiastically. To make this possible, the *Course of Studies* has been organised such that the relationship between the subject matter and activities for studying nature with bearing stronger minds of objectives through observation and experiments is clearly described in Subsections 1 and 2 entitled "Objectives" and "Contents" respectively.

In this manner, it was thought that greater emphasis should be placed on observation and experiments. The aim was to foster the development of the students' capability for scientific thought, judgment and power of expression through self-initiated inquiries using the methods of observation and experiments. Various innovative approaches to describing the Subsection dealing with "Contents" were considered in order to accomplish this aim.

In the view of this situation, an effort was made to describe the "Minor Topics" in the "Contents" Subsection of the new *Course of Studies* in such a way as to encourage more vigorous inquiries and investigations by the students. This was done, for example, by indicating that "the rules governing… should be found by conducting observations and experiments concerning… bearing stronger mind of objectives…" Activities for studying nature through observation and experiments have been described in the

"Contents" Subsection in such a way that they are linked to the subject matter of science education. In organising the contents in this manner it was felt that it would not be suitable to describe the specific procedures for conducting observations and experiments or the materials and tools to be used, as the *Course of Studies* is intended to serve only as the basic framework of the curriculum. Therefore, the description in the "Contents" Subsection only states that observations, experiments and other investigative studies should be conducted and that the students' abilities and desire or keeness to study nature should be fostered through such inquiries and investigations. The description emphasises the necessity of active participation by the students in acquiring knowledge and in forming intellectual concepts with special attention to acquiring knowledge and in forming intellectual concepts and with special attention to relationships with each phenomenon and fact.

4. The contents have been organised with greater emphasis placed on the connections between familiar natural things and phenomena and learners' everyday life, as well as on the results and benefits of science and technology. This was done to make the subject matter of science education more appealing and interesting to the students and integrated into other subject matters.

This consideration also received substantial emphasis in the present *Course of Studies*. In order to bring the subject matter of lower secondary school science education closer to the students, care was taken to relate the contents of the new *Course of Studies* to things familiar to the students in their immediate surroundings. Subject matter dealing with information technologies, new materials and energy has been included as a new topic in the science and technology and human beings section.

5. Computers and computer communications or information technologies should be used as needed in teaching students about science. An attempt was made to clearly identify the role of computers and information technologies in science education in the future and to provide for ways in which computers can be utilised suitably and positively in science instruction.

In using computers and information technologies in science education, thorough consideration should be given to the aims set for science instruction and the relationship computers have with the attainment of those aims. The use of computers and information technologies should be based on a clear understanding of these points.

Let us assume that the objectives of science education are to emphasize the importance of observation and experiments, to encourage self-initiated inquiry and investigation by the students, and to foster independent and creative learning activities. It is necessary to examine the roles that computers can play in attaining each of these objectives and the ways in which computers can support the study of science.

The use of computers and information technologies are described in the following way in the new *Course of Studies* for lower secondary school science education. "Consideration should be given to the effective use of computers and information networks as needed in teaching each area of study, such as in searching for and retrieving information during the course of observation and experiments, in processing experimental data or in performing experimental measurements." (Section 3: Preparation of Teaching Plans and Treatment of Contents.)

The salient points of this description include mention of the use of computers and information networks and also the clear distinction made regarding the ways in which they are to be used.

The course of observation and experiments that is mentioned here means the process of study per se. It refers to the study procedure which involves the identification of a problem, the gathering and processing of information, and the forming of general conclusions based on the results.

Various examples can be cited in connection with information searches and retrieval. These include a search for issues that are to be resolved in conducting research on a particular theme, retrieval of education materials and tools to be used in conducting an observation or experiment, referencing of information on the properties of chemicals or chemical substances, retrieval of information regarding permanent stars or planets of the universe, and retrieval of classifications of animals, plans, minerals and rocks. In these examples, it is intended that computers and information networks will be used as actual tools for supporting the study activities initiated by the students on their own accord.

The capabilities of computers and information networks lend themselves well to such tasks as the processing of experimental data or the creation of graphs through exploring the bulk of information before them. By inputting and processing data or keywords measured in an experiment and then outputting the results in the form of a graph and context, students should be better able to discover the relevant laws of nature and this, in turn, should lead to further study of new things and encouragements.

In carrying out experimental measurements, for example, it is important that the students make their own sensors for detecting light, temperature, sound, pressure and other phenomena. By linking these sensors to a computer and following the changes in the measured data in real time during the course of an experiment, students will be able to grasp changes in phenomena quantitatively. It is anticipated that this will encourage further study which will lead to the discovery of still other natural laws.

It should be noted that the description given in the *Course of Studies* concerning the use of computers and information networks in teaching science does not suggest such things as drills, tutorials or simulations. Many of the simulation software programmes seen nowadays are in fact being used as substitutes for observation and experiments. It would be a grave situation if there were teachers who use this simulation software because they attach little importance to observation and experiments as forms of direct experience.

The following are examples of computer software for the use in science education which are in accord with the principles underlying the latest revision of the *Course of Studies*. It is hoped that these tools will be developed and used in the future.

1. Information retrieval
    - Retrieval of plant classifications (as a method of learning different types of plants).
    - Retrieval of animal classifications (types of birds, fishes, etc.).

- Retrieval of rock and mineral classifications.
- Retrieval of matter classifications (properties, solubility, solids, liquids, gases, etc.).

2. Processing, tabulating and representing graphic experimental data
   - Totaling and processing of experimental data.
   - Processing graphic representation of experimental data (software for creating scientific graphs).
3. Experimental measurements and tools in science education
   - Sensors, and other tools made by students themselves.
   - Experimental measurement of the melting point of naphthalene and para-dichlorobenzene.
   - Experiments on adiabatic expansion.
   - Measurement of heat release in neutralised titration.
   - Measurement of heat generated by passage of an electrical current.
   - Experiments concerning Ohm's law.
   - Dynamic experiments involving light and sensors.
4. Continuous recording of fixed point observations
   - Continuous measurement of changes in temperature, atmospheric pressure and humidity over a set period of time.
   - Continuous measurement of changes in wind direction and velocity over a set period of time.
   - Continuous measurement of rainfall over a set period of time.
5. Computer communications
   - Exchanges of information on teaching materials, methods of instruction and natural environment survey results.
   - Exchange of information on locations for collecting live specimens for educational use, places where specimens are raised or kept and best ways of obtaining experimental specimens for educational use.

CASE STUDY 1: DEVELOPMENT AND EVALUATION OF THE 'HYPER SCIENCE CUBE II'

Title of the Software:

Hyper Science Cube II

Objectives:

- To be familiar with computers through exploring into the materials.
- To realize the cooperation of human beings and nature.
- To acquire the science process skills including presentation skill.
- To enjoy science.
- To do science.
- To become familiar with energy and its related fields.

Target:

- Lower and upper secondary school students.

Mode or Learning Theory:

- Constructivism.

Media:

- Computers and LCDs.

Software used:

- Hypercard and specially developed tool "Multimedia Tool Kit".

Developer:

- Specially formed research group including specialists from Universities, software companies, hardware companies and schools.

Budgets:

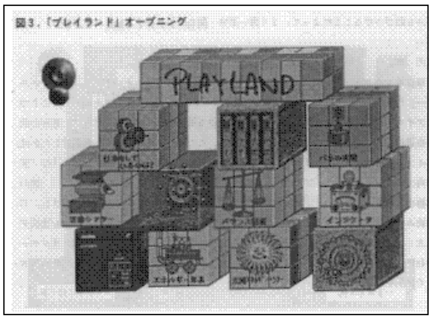
- Some from the Ministry of Education, Science, Sports and Culture, Japan and others from other companies.

Year developed:

- 1991

Sample Displays:

Opening of the Software



Opening display of the Playland

Solar Energy Tour

Pull-down Table of Research on Energy

CASE STUDY 2: DEVELOPMENT AND DISSEMINATION OF THE 'WORLD OF ANIMALS'

Title of the Software:

- The World of Animals

Objectives:

- To become familiar with computers through exploring into the materials.
- To realize the importance of classification.
- To know the process of science experiments on the screen before carrying out real experiments.
- To enjoy the games and quizzes.
- To realize the existence of animal life.
- To do science.

Target:

- Lower and upper secondary school students.

Mode or Learning Theory:

- Problem solving and games and simulations.

Media:

- Computers and CDs.

Software used:

- C+ and Visual Basic.

Developer:

- Specially formed research group including specialists from Universities, software companies, hardware companies and schools and Science Education Centre.

Budgets:

- Some from the Ministry of Education, Science, Sports and Culture, Japan and others from other companies.

Year developed:

- 1998

Sample Displays:

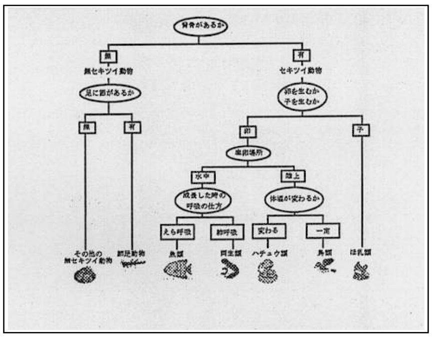
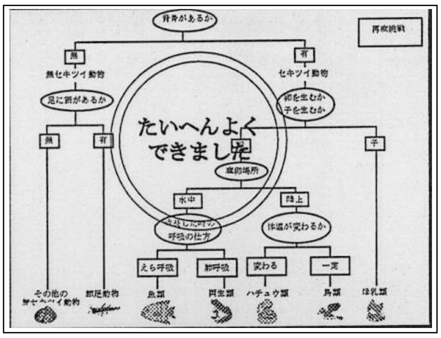
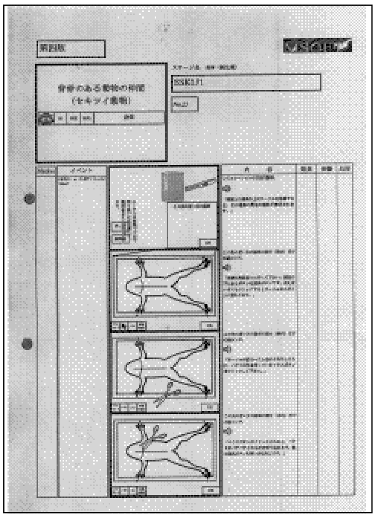


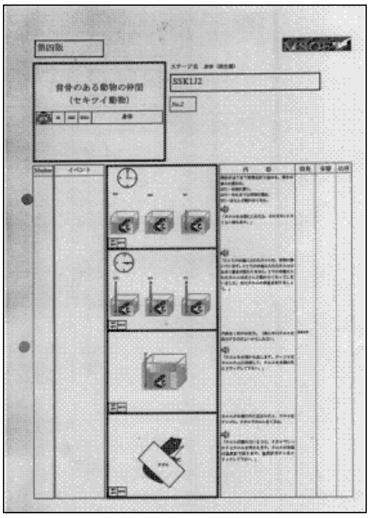
Diagram of Contents



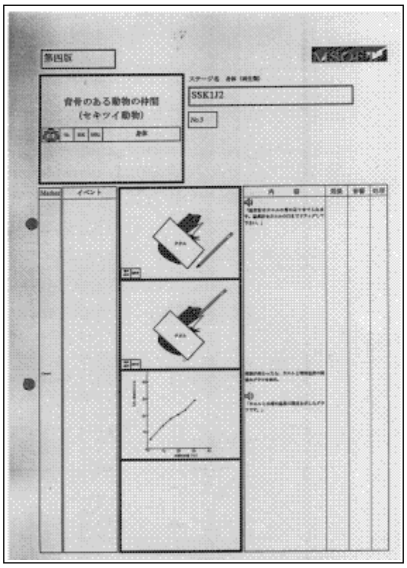
Classification Problem Solving



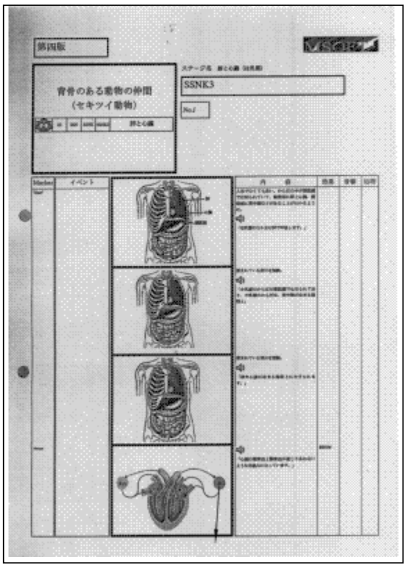
Process of Experiment (1)



Process of Experiment (2)



Process of Experiment (3)



Observation of Human Inner Organs

CONCLUSION

It would not be wrong to say that, except for a few cases, the introduction and utilization of computers and information networks in school science education have just started in Japan. Even though the progress of several technologies especially those concerned with new types of education system is so rapid, it would be better to reconsider that in order to carry out the education reform the 'requirement-pull' will have much higher possibilities in success than 'technology-push' as J.K Glennan, summarised with the survey of innovation in his study in 1973.

If there are concerns about the future of science and technology education in Japan, greater reflection should be given to teaching and learning methodologies, the way in which education is conducted, student evaluation methods and the manner of conducting university entrance examinations responding to the rapid progress of technologies and the variety of students' interests.