Parallel Curriculum of Biomedical Engineering Subjects with Rotational Experimental Project for Interdisciplinary Study Field

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ABSTRACT

Biomedical Engineering is an interdisciplinary study field spreading over mechanical engineering, electrical engineering, and material engineering, which are bound with medicine. Special fields of biomedical engineering should be developed on the wide fundamental engineering base, which require a long distance of study. A parallel curriculum of several engineering subjects, which includes basics and application, with a rotational experimental project has been designed for undergraduate courses to cover wide basic field of "biomedical engineering" and to stimulate motivation of study, simultaneously. The results are evaluated with questionnaire to students.

Keywords: Interdisciplinary Study Field, Biomedical Engineering, Rotational Experimental Project, Parallel Curriculum

1. INTORDUCTION

"Biomedical Engineering" is an interdisciplinary study field spreading over mechanical engineering, electrical engineering, and material engineering, which are bound with medicine (Fig. 1). The biomedical engineering field consists of both bio-mimetic technology and application of engineering to medicine. The field includes "Robotics", "Medical Instrumentation" (Fig. 2).

Biomedical engineering is not an interface between engineering and medicine, but an independent fundamental field to contribute to a variety of applications. The origin of biomedical engineering is technology on human and many engineering methodology has been progressed from the field.

Recently, most of subjects in science have become not compulsory but optional to high school students in Japan, which causes wide variation on academic background of students in the department. Additionally, many students tend to abandon buildup approach subjects, which causes decrease in the number of students who choose the scientific field.

Special fields of biomedical engineering should be developed on the wide fundamental engineering base. To master the basic, a long distance of study is required. To keep motivation for studying the challenging field during the monotonous basic study period, stimulation is necessary for students from application subjects. The biomedical engineering field is easy to understand contribution to the society, because many of its outcomes are applied to human through healthcare technology.

2. PARALLEL CURRICULUM

The curriculum for biomedical engineering has several problems as follows:

1) Multi-disciplinary field demands broad fundamental knowledge.
2) Variation of preparative educational background makes it difficult to make common sense among students.
3) Large amount of monotonous basic study makes it difficult to keep motivations to study the challenging new field of engineering.

To overcome these problems, "Parallel Curriculum of Biomedical Engineering Subjects with Rotational Experimental Project" has been designed in the department instead of the buildup approach (Fig. 3).

The mission of biomedical engineering project is to educate an engineer, who understand human with a background of

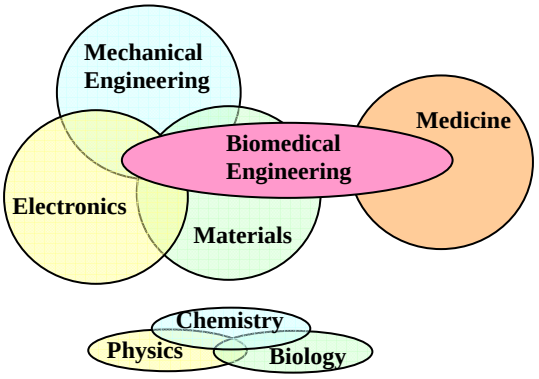

Fig. 1: Biomedical engineering field.

fundamental engineering and has an ability to create things adaptive to human and environment. The project contributes engineers, who develop technology for diagnostics treatment in the healthcare field and design a nursing-care robot in the welfare field, to aging society with a falling birthrate.

Through the biomedical engineering program, students should attain:

(a) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context, with the background of study on DNA (deoxyribonucleic acid) about origin of life, evolution and adaptation, and on technological history about evolution of human,
(b) an understanding of professional and ethical responsibility of engineer on life and health for society and environment,
(c) an ability to apply knowledge of mathematics, physics, chemistry, and biology and informatics to biomedical engineering,
(d) an understanding of theoretical background on mechanics, electronics, and physiology,
(e) to design and conduct experiments on electronics, mechanics, materials and systemics, as well as to analyze, make measurements and interpret data from living systems,
(f) an ability to use the techniques, skills and modern engineering tools necessary for engineering practice,
(g) an ability to identify, formulate, and solve problems at the interface of engineering and biology, associated with the interaction between living and non-living materials and systems,
(h) to design system, component, or process to meet desired needs on problem of healthcare, welfare and nursing care within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability,
(i) an ability to communicate effectively and internationally in multi-disciplinary teams,
(j) a recognition of the need for, and an ability to engage in life-long learning,
(k) an ability to function on multi-disciplinary teams.

To achieve above education objectives, core courses of “Fundamental Seminar for Biomedical Engineering”, “Rotational Experimental Project”, “Biomedical Engineering Seminar” and “Bachelor Thesis” are prepared in parallel with “Fundamental”, “Common”, “Mathematics and Information”, “Measurement and Systems”, “Electronics and Mechanics”, and “Materials and Medicine” courses in the curriculum. Each course includes basic and applied contents simultaneously, which enables to attain fundamental engineering sense, and ability for communication, presentation and designing through understanding human from the multi-disciplinary viewpoints of engineering and medicine.
“History of Technology” and “Ethics in Engineering” offer opportunity to learn responsibility as a global engineer;

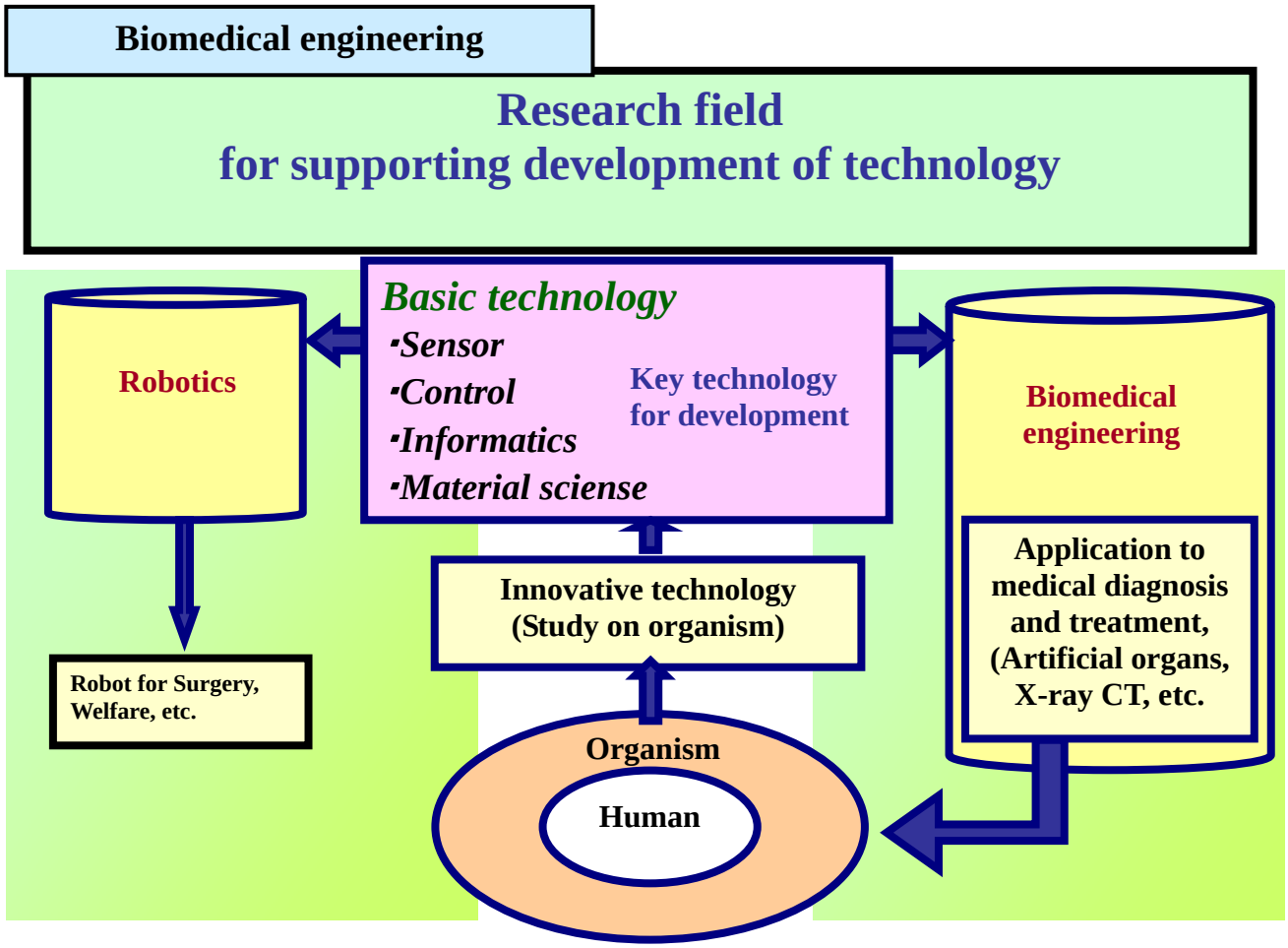

Fig. 2: Robotics and biomedical courses.

"Exercises on Mathematics", "Exercises on Physics", "Exercises on Chemistry", "Introduction to Biology" and "Information Processing" educate ability to apply basic knowledge of science; "Introduction to Medical Engineering", "Electronics", "Introduction to Mechanics", etc. educate theoretical background of biomedical engineering; "Rotational Experimental Project", "Fundamental Seminar for Biomedical Engineering", "Biomedical Engineering Seminar", and "Bachelor Thesis" offer opportunity to learn ability for identification, designing, communication, life-long learning. Courses are listed in Table 1.

Table 1: Biomedical engineering courses for undergraduate students (unit of credit hours: one unit corresponds to eleven hours). *compulsory.

(Fundamental Courses)
Calculus (6)
Linear Algebra (4)
Fundamental Information Processing (4)
Physical Experiment (4)

(Common Courses)
Fundamental Seminar for Biomedical Engineering (2)*
Experiments on Electronics (4)*
Experiments on Systems Engineering (4)*
Experiments on Medical Engineering (4)*
Experiments on Bio-measurement Engineering (4)*
Biomedical Engineering Seminar (2)*
Bachelor Thesis (8)*
Introduction to Medical Engineering (2)
History of Technology (2)*
Exercises on English for Engineering (2)*
Ethics in Engineering (2)*
Basic Study on Patent of Medical Engineering (2)

(Mathematics and Information Courses)
Exercises on Mathematics (4)*
Exercises on Applied Mathematics (4)*
Fundamentals of Computer System (2)*
Basic Concepts of Information Processing (2)
Information Processing (4)*
Statistics (2)*
Signal Processing (2)
Bio-informatics (2)

(Measurement and Systems Courses)
Measurement Engineering (2)
Psycho-physiological Engineering (2)
Sensory Organ Engineering (2)
Imaging Technology (2)
Control Engineering (2)
Human Interface (2)
Mechatronics (2)
Robot Engineering (2)
Bio-control Engineering (2)
Bio-robotics (2)

(Electronics and Mechanics Courses)
Exercises on Physics (4)*
Electrical Circuits (2)
Introduction to Electronics (2)*
Electronics (2)
Introduction to Mechanics (2)*
Biomechanics (2)
Bio-rheology (2)
Device Engineering (2)
Bio-physical Engineering (2)
Tribology(2)
Micro-Machining (2)
Sensor Engineering (2)

(Materials and Medicine Courses)
Exercises on Chemistry (2)*
Introduction to Biology (4)*
Polymer Engineering (2)
Biomaterials (2)
Bio-physical Properties for Human Body (2)
Biosystems Engineering (2)
Tissue Engineering (2)
Artificial Organs (2)
Life Support Technology (2)
Innovative Technology (2)

(Liberal Arts Courses)
Liberal Arts (32)*
Foreign Language (8)*

(Partnership Courses)
Internship (2)
Career Design (4)

Table 2: Biomedical engineering courses for postgraduate students (unit of credit hours: one unit corresponds to eleven hours).

Doctor Courses

Special Research on Robotics (12)
Special Research on Biomedical Engineering (12)

Master Courses

Advanced Course on Bio-informatics (2)
Advanced Course on Psycho-physiological Engineering (2)
Advanced Course on Robotics (2)
Advanced Course on Control Engineering (2)
Advanced Course on Biophysics (2)
Advanced Course on Bioelectronics (2)
Advanced Course on Biomaterials (2)
Advanced Course on Medical Engineering (2)
Advanced Course on Medical Welfare Systems (2)
Advanced Course on Medical Micro-device (2)
Advanced Course on Biomeasurement (2)
Advanced Course on Biomechanics (2)
Literature Research for Thesis (8)
Special Research for Thesis (8)

3. ROTATIONAL EXPERIMENTAL PROJECT

Twelve core faculties were collected to cover variety of biomedical engineering field through collaboration among institutes for research project for medical engineering research center (Fig. 3). Each faculty is in charge of an independent

theme for the rotational experimental project, as well as in charge of each advanced course in the master courses (Table 2).

"Rotational Experimental Project" consists of four courses: "Experiments on Electronics", "Experiments on Systems Engineering", "Experiments on Medical Engineering", "Experiments on Bio-measurement Engineering". The themes of the projects are "Manufacture a solar battery and a photo-sensor", "Design of an electric circuit for measurement of an electrocardiogram", "Measurement of interaction between biological cells and synthetic materials", "Manufacture of a robot finger", "Control of a robot finger", "Micromachining with photolithography", "Measurement of viscosity of fluid", "Manufacture of a electro stethoscope", "Design of an electric circuit for an intelligent sensor", "Manufacture of a position sensor for robotics", "Measurement and analysis of bio-signals". In each project, students design and conduct experiment in a small group activity for four weeks. Each student experiences every theme one by one.

4. ENVIRONMENTAL DESIGN

Each laboratory room for the experiment is located in the next door to corresponding faculty's office, which is convenient for students to get advice from the faculty about the project at any time. The laboratory room is also equipped for the postgraduate students' research work, which motivates undergraduate students to advanced study about the experiments. The equipments are a three-dimensional position tracer, an eye tracking system, a bio-signals monitor system, a thermography, a large spherical concave display, a computer server, a robot arm for surgery, clean benches, incubators, an scanning electron microscope, a confocal microscope, a micro-machining system of stereo-lithography, and an universal testing machine. Some of them are equipped in a specially designed room such as a soundproof room, clean rooms, and a magnetic shielding room.

In the department house, each floor is divided into several research groups, which are Bio-informatics, Psycho-physiological Engineering, Robotics, Control Engineering, Biophysics, Bioelectronics, Biomaterials, Medical Engineering, Medical Welfare Systems, Medical Micro-device, Biomeasurement, and Biomechanics.

Each space of the group consists of a faculty's office, a laboratory for research staffs, and laboratory for undergraduate students. The arrangement of rooms enables for young students to learn many things from seniors and to extend their interest to research works in their group activities.

5. RESULTS

Applicants for admission to the biomedical engineering department included radiological technologist, clinical engineer, and clinical laboratory technologist, who want to get ability for more creative work than daily regular work in the healthcare field. Students, who have such kind of professional backgrounds, applied not only for postgraduate courses, but also for undergraduate courses of newly established biomedical engineering department. Students with a variety of academic

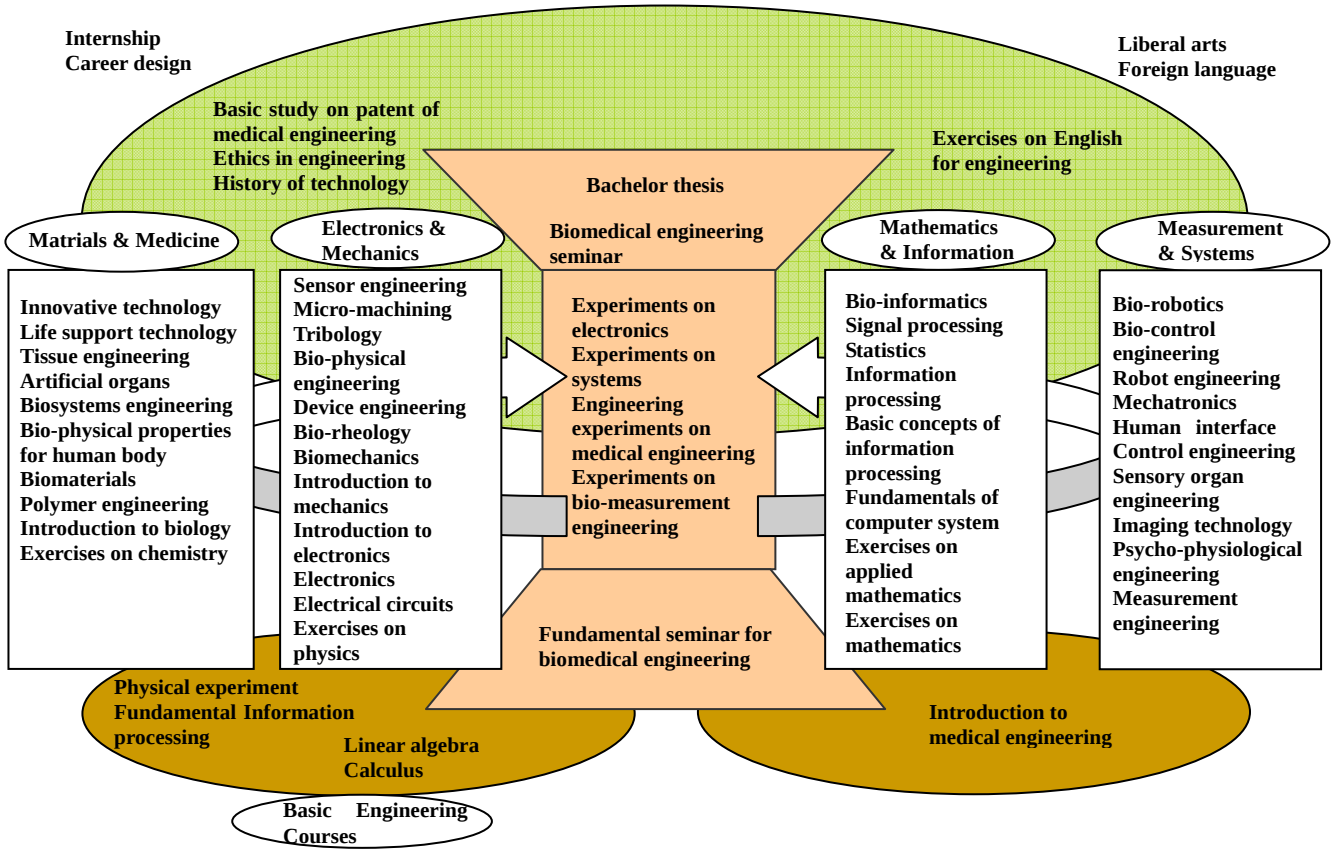

Fig. 3: Parallel curriculum of biomedical engineering subjects with rotational experimental project.

background about mathematics and science were admitted to the department.

The result of a questionnaire to students in the first month shows most of students feels difficulties about the large number of subjects prepared in the first semester. "Fundamental Seminar for Biomedical Engineering" with a spontaneous research project in a small group activity about biomedical engineering field helps them to keep motivation to study. Especially "Physics" and "Mathematics" are the most difficult subjects under wide variation of academic backgrounds, because they tend to have buildup approaches. The most popular subject was "Introduction to Biology", which includes anatomy and Physiology. The reason why "Introduction to Biology" is popular to the student is that the subject does not seem like one with a buildup approach, and includes many contents, which is new to students.

The results of a questionnaire to students (Table 3) at the end of the second semester show that:

1) Sixty-one percent of students have not understood the mission profoundly,
2) Seventy-two percent of students feel the mission appropriate,
3) Eighty-one percent of students feel that the relation between courses is appropriate,
4) "Introduction to Biology" and "Exercises on Physics" need more school hours,
5) the average self-schooling period among students was a quarter of school hours and is not enough in most of students,
6) "Introduction to Biology" and "Rotational Experimental Project" gave students motivation for advance study,
7) the contents of "Introduction to Biology" and "Exercises on Physics" are ingenious,
8) equipments are good for study,
9) the grade is consistent with self-evaluation in "Introduction to Biology",
10) the position of "Liberal Arts" in the curriculum is not understandable for several students.

Table 3: Questionnaire for curriculum

1) Do you understand the mission of curriculum?
2) Do you think the mission is appropriate?
3) Is the relation between courses appropriate?
4) Is the learning period of each subject long enough to achieve the corresponding objective?
5) How many hours do you study in total?
6) Which subject advances your motivation?
7) Which subject is ingenious?
8) Is equipment good enough for leaning?
9) Can you understand criteria for evaluation?
10) Is the grade consistent with your self-evaluation?

Opinions of parents collected at the lab-tour and at the interview show worry about the future career and license after graduation. "ME (Medical Engineering) engineer", "Bioinformatics Engineer", and "Fundamental Engineer" are related license in the course. Some parents pointed out that English conversation class should follow the individual level of learning in the office hour. Most of parents evaluate "Rotational Experimental Project" successful.

Manufacturer, especially on parts, printing, hybrid product, security system, food, pharmacy, medical device and healthcare, welcomes broad ability about basic engineering: a mechanical engineer should understand basic electronics, for example. The motivation for studying biomedical engineering gets attention of industry, because most of companies are preparing for new projects relating to healthcare. Many manufacturers request mechanics and electronics more than materials.

6. DISCUSSION

Recently, progress in computer technology and cell culture technique inspires collaboration between engineering and medicine. Osaka institute of Technology collaborates with several institutes: a) Department of Thoracic and Cardiovascular Surgery & Cardiovascular Center, Kansai Medical School, b) Bioinformatics Engineering, Graduate School of Information Science and Technology in Osaka University, c) Department of Regenerative Medicine and Tissue Engineering, Advanced Medical Engineering Center, Research Institute of National Cardiovascular Center, d) Surgical Assist Technology Group, Institute for Human Science and Biomedical Engineering, National Institute of Advanced Industrial Science and Technology, e) Major in Radiology and Biomedical Engineering, Graduate School of Medicine, The University of Tokyo (Fig.4). The collaboration forms not only the research center for medical engineering [1, 2], which has been established since 2005, but also the base for education of biomedical engineering. To advance research in interdisciplinary field, researchers themselves should be experienced with interdisciplinary field for promoting communication between different disciplines. Faculties, who have various biomedical engineering research backgrounds, inspire motivation of students through "Rotational Laboratory Experiments", which start in the second semester.

In USA, many universities have held biomedical engineering courses. They educate many students with the ingenious curriculum to contribute modern society [3]. In Japan, it is not easy to make biomedical engineering curriculum for undergraduate courses, because of the difference of academic background of high-school students and medical school system, which admit students directly from high school.

To stimulate motivation and keep incentive in applicants of various academic background;

a) study field should be attractive,
b) variation of learning experience should be accepted
c) a buildup approach may not be preferred.

Under these backgrounds, "Parallel Curriculum of Biomedical Engineering Subjects with Rotational Experimental Project" has been designed for biomedical engineering. The motivation is continuously fed back from experiment to each subject, which forms collaborative spirals among courses.

The present curriculum is challenging one, so that less than half of students understand the mission profoundly during the first year of study. Buildup approach in basic learning may be boring to most of students, but the rotational experimental project has been effective to motivate advance study and to find

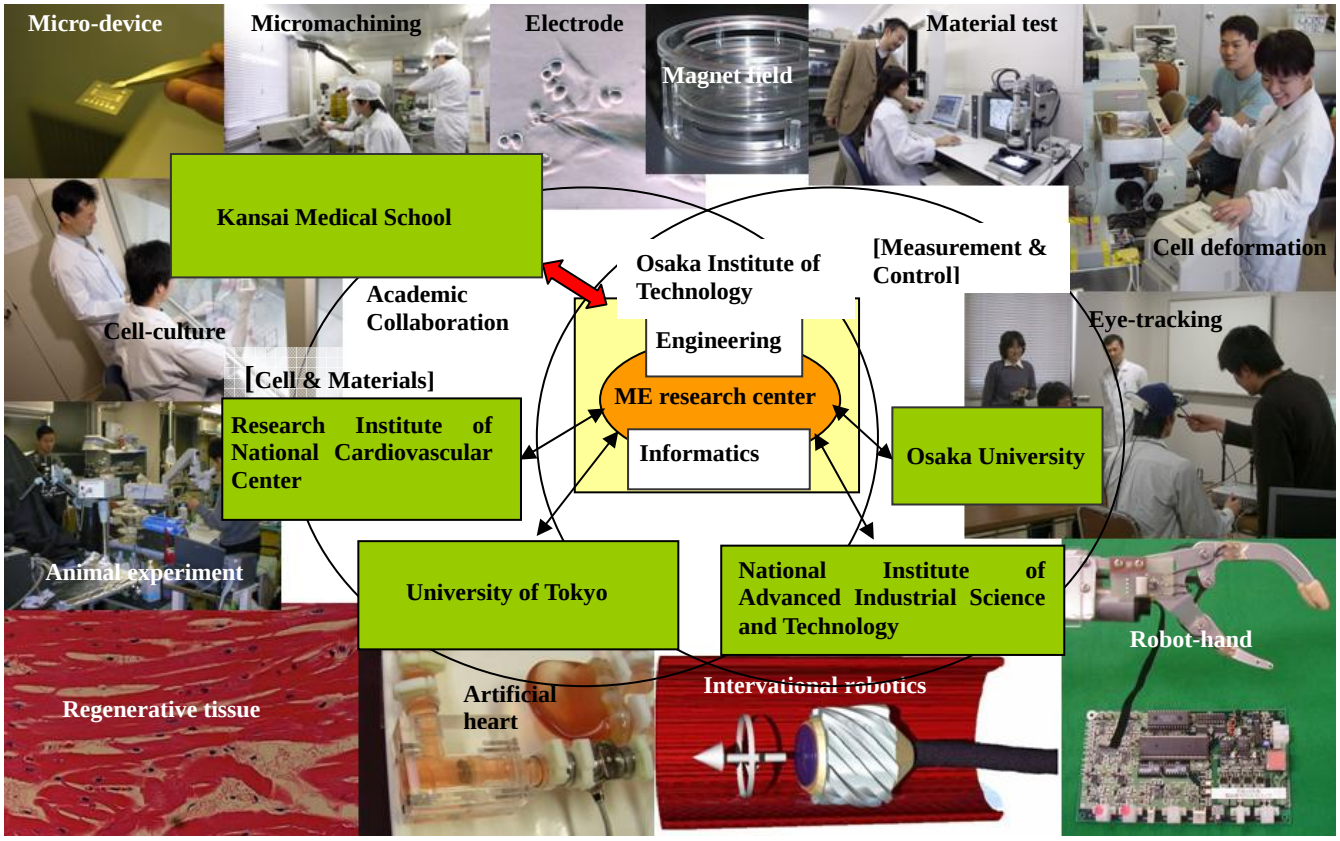

Fig. 4: Academic collaboration for "Medical Engineering (ME)".

basic idea through applications in the multi-disciplinary study field of biomedical engineering. The study field of biomedical engineering may be easy for self-learning, because human itself is subject to be studied.

7. CONCLUSION

A newly designed parallel curriculum of several engineering subjects with a rotational experimental project is effective to cover wide field of "biomedical engineering" and to stimulate motivation of study, simultaneously.

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