Parallel Curriculum between Application and Fundamental Subjects with Rotational Experimental Project for Multidisciplinary Study Field of Biomedical Engineering

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ABSTRACT

Biomedical Engineering is a multidisciplinary study field spreading over between engineering and 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 between application and fundamental subjects with rotational experimental projects has been designed for undergraduate courses to cover the wide basic field of "biomedical engineering" and to stimulate motivation of study, simultaneously. High-schools and industries are expecting the educational system to develop multidisciplinary human resources. The interim report is evaluated with questionnaire to students.

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

1. INTRODUCTION

The biomedical engineering field consists of both bio-mimetic technology and application of engineering to medicine. 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 concepts have been progressed from the field.

A research field of "Biomedical Engineering" has a long history in Japan, and has been developed in laboratories in many universities. An educational field of "Biomedical Engineering", on the other hand, has not been developed in undergraduate level in Japan. Because Japanese has variations in making new words for the similar meaning, more than ten names are used for the name of the departments related to Biomedical Engineering: including Clinical Engineering, Medical Technology, Bio-cybernetics, Bio-robotics.

Osaka Institute of Technology has established a department of "Biomedical Engineering" for undergraduate courses at 2006, and for master and doctor courses at 2007. The department includes two groups of courses: "Robotics" and "Medical Instrumentation" [1].

This report describes about preparation for establishing department, design of curriculum and facilities, and interim appraisal.

2. COLLABORATION BETWEEN ENGINEEIRNG AND MEDICINE

Osaka Institute of Technology has kept collaboration on research works with Kansai Medical University, which is located within walking distance. Two universities signed an agreement for collaboration each other on July 15th 2004: on exchange of information about science and technology, on joint research, on exchange of student, on mutual exchange of faculties.

"Biomedical Engineering" is a multidisciplinary study field spreading over mechanical engineering, electrical engineering, and material engineering, which are bound with medicine. To make collaboration network between research institutes, "Medical Engineering Research Center" was established in March 2005. To promote collaboration between these fields, a research project has been started on "Application of Cultured Muscle Cells on Medical Engineering", which has been supported by a Grant-in-Aid for Academic Frontier from the Japanese Ministry of Education, Culture, Sports and Technology [2]. The collaboration network consists of following institutes: a) Osaka Institute of Technology, b) Department of Thoracic and Cardiovascular Surgery & Cardiovascular Center, Kansai Medical School, c) Bioinformatics Engineering, Graduate School of Information Science and Technology in Osaka University, d) Department of Regenerative Medicine and Tissue Engineering, Advanced Medical Engineering Center, Research Institute of National Cardiovascular Center, e) Surgical Assist Technology Group, Institute for Human Science and Biomedical Engineering, National Institute of Advanced Industrial Science and Technology, f) Major in Radiology and Biomedical Engineering, Graduate School of Medicine, The University of Tokyo. The collaboration forms not only the research center for medical engineering, but also the base for education faculties of the department of biomedical engineering. To advance research in multidisciplinary field, researchers themselves should experience the multidisciplinary field for promoting communication between different disciplines.

3. COLLABORATION WITH HIGH SCHOOL

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 decreases the number of students who choose the scientific field. Career guidance in the high school sometimes introduces students indiscreetly to courses only for technical certification. High school teachers welcome "Biomedical Engineering" as a university program, which encourages students to study a variety of basic scientific subjects. To motivate continuously students to study basic subjects, faculties in the department of biomedical engineering show laboratories on the preparatory schooling, give open lectures even in high schools. Collaborating with the high school teacher, each faculty follows achievement of every student.

4. COLLABORATION WITH INDUSTRY

Faculties have collected comments to the curriculum with interview to industry. Manufacturers, especially on parts, printing, hybrid product, security system, food, pharmacy, medical device and healthcare, welcome broad ability about basic engineering. They thought that 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 for aging society in Japan. Many manufacturers request more mechanics and electronics than materials to maintain production lines. Industry evaluates on-the-job training in laboratory experimental projects in the university in Japan. Some industries propose such type of leaning for freshman to improve design and communication abilities.

5. PARALLEL CURRICULUM

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 medical school system, which admits students directly from high schools.

Special fields of biomedical engineering should be developed on the wide fundamental engineering base. To master the base, 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.

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. 1).

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

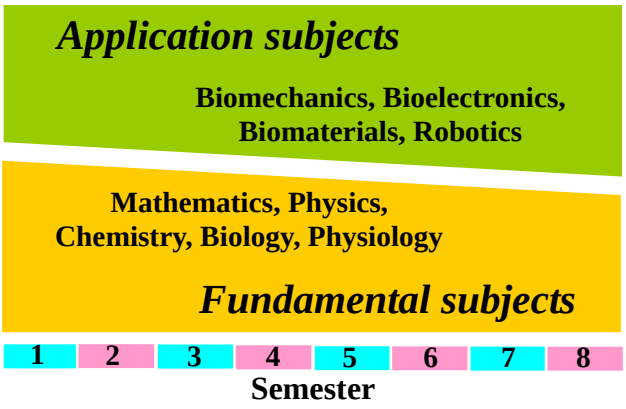

Fig. 1: Parallel Curriculum between Application and Fundamental Subjects.

(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 including freshman's camp (Fig. 2)", "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; "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, and life-long learning.

6. ROTATIONAL EXPERIMENTAL PROJECT

Twelve core faculties were collected to cover variety of biomedical engineering field through collaboration among institutes for research project in medical engineering research center. Each faculty is in charge of an independent theme for the rotational experimental project, as well as in charge of each laboratory (Table 1).

Table 1: Laboratories

Biophysical Engineering Laboratory
Bio-mechanical Robotics Laboratory
Bioelectronics Laboratory
Medical Welfare Systems Laboratory
Bioinformatics Laboratory
Medical Micro-device Laboratory
Biomaterials Laboratory
Biosystems Laboratory
Medical Engineering Laboratory
Bio-control Laboratory
Robotics Laboratory
Welness Laboratory

Fig. 2: Fundamental Seminar for Biomedical Engineering.

Fig. 3: Rotational Experimental Projects.

"Rotational Experimental Project (Fig. 3)" 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", "Motion control for robotics", "Design of an electric circuit for measurement of an electrocardiogram", "Manufacture of a robot finger", "Control of a robot finger", "Micromachining with photolithography", "Measurement of interaction between biological cells and synthetic materials", "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. Faculties, who have various biomedical engineering research backgrounds, inspire motivation of students through "Rotational Laboratory Experiments", which start in the second semester.

7. 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 examples of 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 robotics studio, a biotechnology studio, a soundproof room, a clean room, and a magnetic shielding room.

In the department house, each floor is divided into twelve laboratory divisions. Each space of the laboratory division consists of a faculty's office, a laboratory for research staffs, and laboratory for undergraduate students (Fig. 4). The arrangement of rooms enables for young students to learn many things from

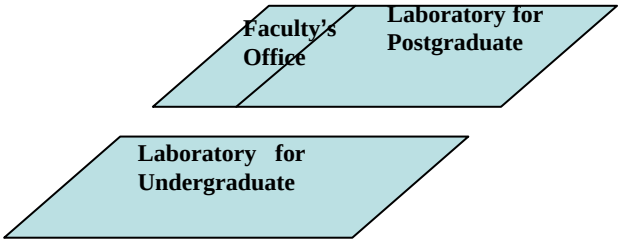

Fig. 4: Laboratory design.

seniors and to extend their interest to research works in their group activities.

8. QUESTIONNAIRE TO CURRICULUM

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 works than daily regular works 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 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" is the most difficult subject under wide variation of academic backgrounds. 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 effect of curriculum has been evaluated with a questionnaire (Table 2) to first class students at the end of the second, the third and the fourth semesters; and to second class students at the first and second semesters. The results of the questionnaire to students (Figs. 5-11) show that:

1) More than sixty percent of students understand the mission profoundly except first class student in one year.
2) More than seventy percent of students feel the mission appropriate.
3) Eighty percent of students feel that the relation between courses is appropriate.
4) "Introduction to Biology", "Exercises on Physics", "Introduction to Mechanics", "Exercises on Applied Mathematics", and "Information Processing" need more school hours,
5) More than half of students think that they have studied for enough hours.
6) The average self-schooling period among students is a quarter of school hours and is not enough in most of students,
7) "Introduction to Biology", "Biomaterials", "Introduction to Mechanics" and "Rotational Experimental Project" give students motivation for advance study,
8) The contents of "Introduction to Biology", "Exercises on Physics", "Sensory Organ Engineering", and "Psychophysiological Engineering" are ingenious,
9) More than 75 percent of students feel that equipments are good enough for leaning,
10) The grade is consistent with self-evaluation in "Introduction to Biology", "Bio-rheology", "Electronics", "Exercises on Physics", and "Exercises on Mathematics"
11) The position of "Liberal Arts" in the curriculum is not understandable for several students.

The present curriculum is challenging one, so that less than half of students understood the mission profoundly during the first year of study. Buildup approach in basic learnings may be boring to most of students, but the rotational experimental project has been effective to motivate advance study and to find basic idea through applications in the multi-disciplinary study field of biomedical engineering. The study field of biomedical engineering should be easy for self-learning, because human itself is subject to be studied.

Table 2: 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?

9. PUBLIC RELATIONS ACTIVITIES

The department house of biomedical engineering accepts more than one hundred visitors of high school students, their parents, and high school teachers a year (Fig. 12). Faculties lecture five hundred students a year, visiting high schools in various suburbs. The open laboratory schools not only for students but also teachers. Exhibitions are displayed in every occasion: campus festival, etc. The results of the challenging curriculum were reported at the final symposium of Tohoku University Biomedical Engineering Research Organization (21st Century Center of Excellence Program in Japan), and at the 47th Annual Conference of Japanese Society for Medical and Biological Engineering in 2008.

Opinions of parents collected at the lab-tour and at the interview show worry about the future career and qualification after graduation. "ME (Medical Engineering)", "Bioinformatics Engineer", and "Fundamental Engineer" are related qualification of the course. Most of parents evaluate "Rotational Experimental Project" successful.

10. CONCLUSION

Interim appraisal is as follows:

1) The new department supplies a field for young comrades to get together, stimulate, and collaborate each other.
2) The new department encourages young students to participate academic conference on medical engineering, of which participants are decreasing in Japan.
3) The new department advances young students motivation not only to gain a clinical qualification but also to continue academic research.
4) Early exposure to familiar case studies opens young students eyes to need for learning various fundamental basic subjects.
5) The new department enlightens people on Biomedical engineering field, which is not only for research but also for education.

Interim appraisal shows that a newly designed parallel curriculum between application and fundamental subjects with a rotational experimental project is effective to cover multidisciplinary study field of "biomedical engineering" and to stimulate motivation of study, simultaneously. The new department shows availability of "Biomedical Engineering" for education.

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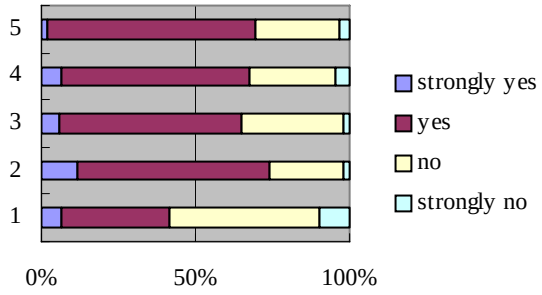

Fig. 5: Do you understand the mission of curriculum? First class: 1, second; 2, third; 3, fourth semester. Second class: 4, first; 5, second semester.

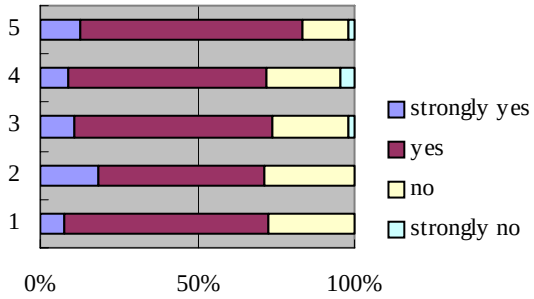

Fig. 6: Do you think the mission is appropriate?

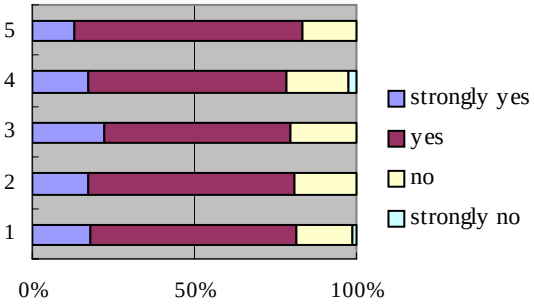

Fig. 7: Is the relation between courses appropriate?

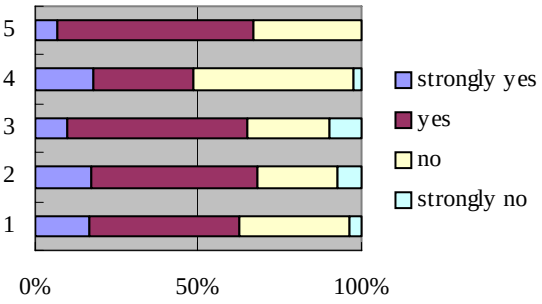

Fig. 8: Do you study for enough hours?

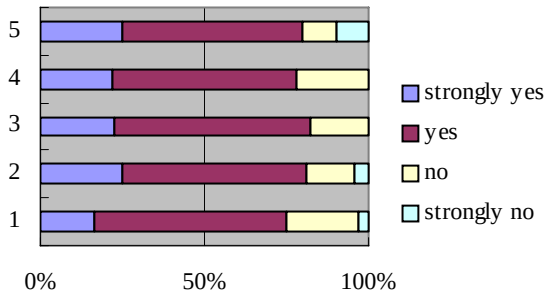

Fig. 9: Is equipment good enough for leaning?

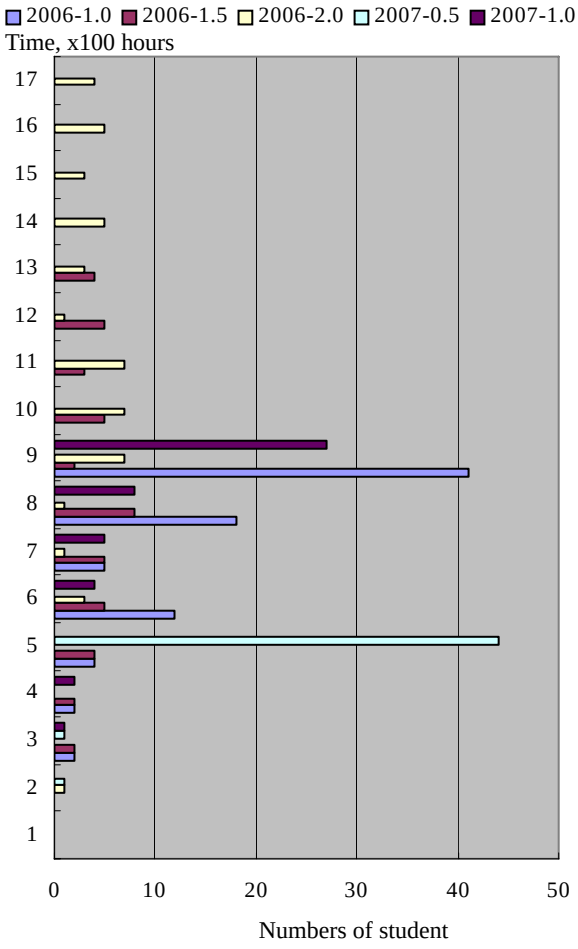

Fig. 10: How many hours do you study in school in total?

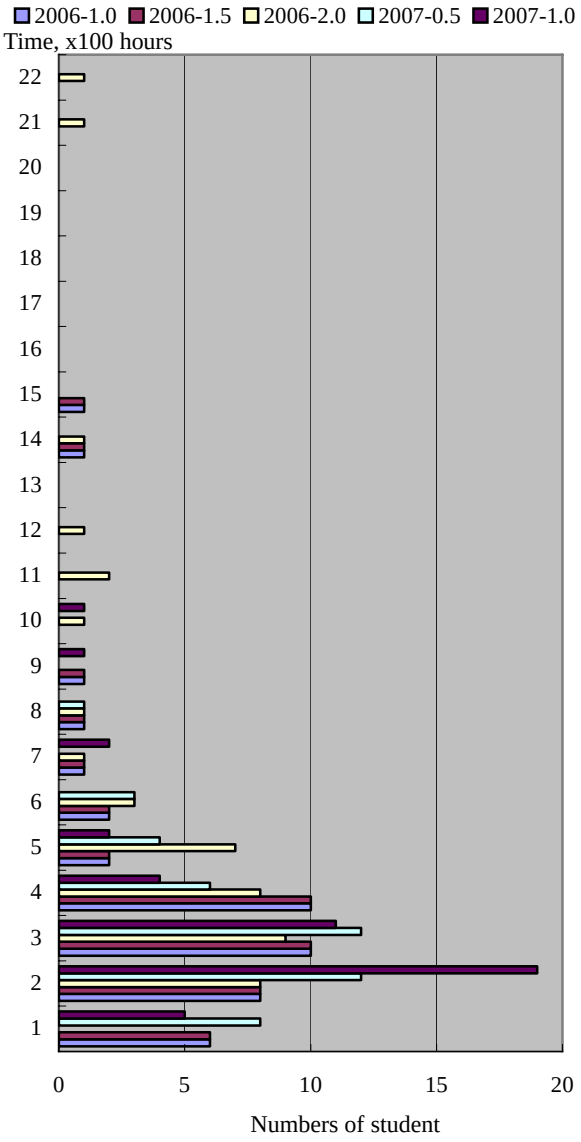

Fig. 11: How many hours do you study for yourself in total?

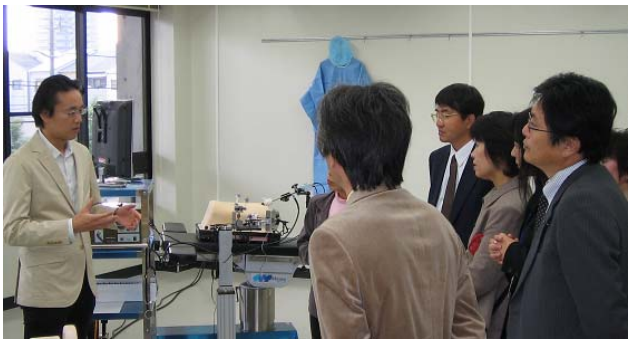

Fig. 12: Department house accepts visitors (robot arm for surgery).