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Does Learning Multidisciplinary Field of Biomedical Engineering Help Pandemic of COVID-19?

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Abstract[1]

The global community has accelerated the spread of the virus. Medicine alone cannot solve the pandemic. Changes of lifestyle enabled by new technology helps to coexist with viruses. The academic field has been divided into each specialized field. Modern communication tools (internet and cloud databases), on the other hand, promote multidisciplinary academic fields. The multidisciplinary field is not just a collection of fields, but a fusion among fields. Many problems in global society cannot be solved by a single disciplinarian. The global society is waiting for a multi-disciplinarian. For students, it is not easy to find the way to learn a multidisciplinary field. This depends on the curriculum, the textbook, the learning team, and the teacher (the adviser). "Biomedical Engineering" is one of the multidisciplinary fields. It has many related fields: biology, medicine, informatics, and engineering. The topic includes case studies related to COVID-19 in 2020 (education for the undergraduate and the graduate courses in Japan and Thailand) based on the author's experiences: from cross cultural to symbiosis.

Keywords: *Multidisciplinary Field, Learning, Biomedical Engineering, COVID-19, Communication and Students*

1. Introduction

Infections are unavoidable problems for humankind. They are one of the main causes of death. For human society, there is a danger of an infection becoming a pandemic. Viruses are transmitted from person to person. Public Health as an

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academic discipline recommends restricting face-to-face communication in the pandemic (Hashimoto, 2020a). Students' group activities also are limited in universities in the pandemic. Students feel inconvenience under restrictions. Students design the way to manage campus life during the pandemic by themselves. The design is related not only to improvements of the lifestyle, but also to project based learning (Hashimoto, 2008). In an online project, students exchange ideas about designing systems to improve pandemic-related lifestyles. Through activities, students learn how to apply methodologies related to their basic subjects. The learning leads students to their future work. It inspires innovation of lifestyle (Hashimoto, 2018) after a pandemic.

Project-based learning is an effective case study for education in interdisciplinary fields. Biomedical engineering is one of the interdisciplinary fields (Hashimoto, 2007, Linsenmeier, 2003, 2020). It has many related fields (Hashimoto, 2016). Biomedical engineering is also closely related to infectious diseases. One of devices, which are used in the severe respiratory disorders of infectious diseases, is the extracorporeal membrane oxygenator (ECMO) (Hashimoto, 2018). ECMO is the fruit of biomedical engineering as an assist device for oxygen deficiency due to respiratory disorders. Biomedical engineering as an academic discipline that supports healthcare is deeply related to infectious disease control.

This article describes the results of an educational attempt at Mahidon University (Thailand) and Kogakuin University (Japan) in 2020 for students in classes related to undergraduate and graduate biomedical engineering courses. Although COVID-19 had a great impact on students' lives, they were unaware of the relevance to what they were learning. Covid-19 was taken up as a topic as a trigger to seriously consider the application of interdisciplinary field learning content (Hashimoto, 2020b). Students considered the topic, while answering questionnaires on COVID-19. Students create reports on the topic: the problem to be solved, methods to solve the problem, expected results, and contributions to the society. Through classes, students discover relationships between different learning subjects in the interdisciplinary field of biomedical engineering.

2. Methods

The learning courses of “Biomedical Engineering” welcomes undergraduate and graduate students every year. The textbook of “Biomedical Engineering” includes the following contents (with case studies) (Hashimoto, 2013). The contents include medical case studies to guide students to understand the relationships between medical topics and basic subjects of engineering.

1) Organisms and Machines: comparison between biological system and engineered system (Individual differences in biological objects. Technical terms).
2) Units and Measurement (Biomeasurement, Electrocardiogram).
3) Materials: deformation, destruction (Red blood cell destruction).
4) Flow: viscosity, flow reisitance, velocity profile, turbulent flow (Shunt, Cannula, Blood circulation, Pulsatile flow).
5) Energy: temperature, efficiency, osmotic pressure (Oxygenator, Dialyzer).
6) Movement: balance between forces, lubrication (Joint prosthesis, Clot formation, Heart valve prosthesis).
7) Design and Machining: surface roughness (Artificial organs).

In the courses, students answer several questions related to COVID-19: Japanese undergraduate students in “Biomechanics”, mastercourse students in “Advanced course of biomechanics” in Kogakuin University, and Thai undergraduate students in “Biomechanics” in Mahidol University in 2020. COVID-19 is a disease caused by a new type of coronavirus (SARS-CoV-2). The virus has caused a pandemic. The pathology has not been elucidated. Several treatments have been tried. While the unique answer to each question has not been decided yet by specialists, the questions give motivation to students to find topics of global multidisciplinary problems.

2.1. Questions

Several questions were prepared to help students understand the route of virus transmission not only statistically but also logically: not only based on public health, but also based on microbiology. The main pathway for SARS-CoV-2 is hypothesized to be via the air between the human respiratory systems.

(1) The following are effects of vaccine: “True” or “False”.

1) Antibodies to the virus are produced?
2) The vaccine causes infection?
3) Preventing viruses from invading a cell?
4) Stops infection?
5) Reduced chance of infection?
6) No more transmittance of virus to your neighbors?
7) After infection, condition does not become severe?
8) Will side reactions happen?
9) The effect lasts?
10) Vaccination proof is more effective than PCR negative proof?

(2) Select your behavior in the past two weeks to be “free of COVID-19 infection”.

1) Asymptomatic; I have been facing others in normal life.
2) Facing others in normal life, I have been paying attention to disinfection: masks, and distancing from others.
3) I have been managing my own health by measuring body temperature without facing others.
4) Facing others in normal life, I have been checking for negative signs of COVID-19 infection by a PCR (polymerase chain reaction) test every day.
5) I have been facing others in normal life, taking medications to control COVID-19 symptoms.

6) I have been facing others in normal life, after receiving the vaccine against SARS-CoV-2 virus.
7) I have been facing others in normal life, after confirmation of negative signs by a PCR test after recovery from COVID-19.

(3) Select three effects of wearing masks on COVID-19.

1) Prevent the outflow of the virus.
2) Enhance immune capacity by maintaining humidity in the oral cavity.
3) Reduce splashing of water droplets containing virus that accompany sneezing.
4) Prevent elevation of the body temperature.
5) Prevent the inflow of the virus.
6) Prevent direct touching by your hands to the mouth (or the nose).

(4) Choose three methods related to COVID-19 to directly reduce your chances of infection.

1) Wash your hands frequently.
2) Do not eat with bare hands without washing hands.
3) Disinfect the area you touch with alcohol.
4) Do not get together with many people.
5) Do not eat meals, which are exposed to the space of everyone's conversation, at the buffet.
6) Do not stay in a place with poor ventilation.
7) Keep a distance from others.
8) In a room with multiple people, refrain from the following action: talking, deep breathing, and singing a song.
9) Do not shake hands with others.

(5) Choose three answers to directly reduce the probability of the movement of COVID-19 virus from yourself to others.

1) Wash your hands frequently.
2) Wear a mask when singing.
3) Use alcohol to disinfect your hands, and to disinfect the areas you touch.
4) Do not go into crowds.
5) For sneezing and coughing, cover the mouth and the nose with sleeves and a handkerchief.
6) Do not stay in a place with poor ventilation.
7) Keep a distance from others.
8) Wear a mask when speaking.
9) Do not touch where many persons touch.

(6) Which is the effect of virus test? Select two choices.

1) To find a positive test for isolation.
2) For statistics.
3) To find the infection route.
4) Negative check for occupation: medical care, nursing.
5) Certificate for a negative test.
6) Getting an infection during the test: contact with patient.

2.2. Topic Selection

The problem of COVID-19 includes many topics to be solved. Students try to find a new idea related to the topic, after answering several questions.

(7) Choose multiple answers from the following future technologies related to COVID-19 that you would like to realize.

1) Automatic generation of vaccine.
2) Automatic determination of effectiveness of vaccine without clinical trials.
3) Detection of cytokine (substance secreted by cells) release syndrome.
4) Diagnostics without facing the patient.

5) High-speed diagnosis of inspected data by artificial intelligence.
6) Prediction of infection.
7) Portable respirator.
8) Implantable oxygenator.
9) Technology that reduces oxygen consumption in living tissues.
10) Face-to-face communication technology without vocal conversation.
11) Telemedicine.
12) Medical robot.
13) Remote care.
14) Nursing robot.
15) Remote childcare.
16) Childcare robot.
17) Barber robot.
18) Artificial reality.
19) Remote sports.
20) Self-driving car.
21) Everyday activity tracking technology.
22) Everyday behavior monitor.

2.3. Your Proposal

In relation to COVID-19, students made reports. Students selected topics in relation to biomedical engineering. They discuss their own ideas quantitatively, using illustrations for explanation. The report should include following items: an informative title, the motivation, methods, and contributions to society.

2.3. Presentation in Multidisciplinary Conference

Students made presentations in the “World Multi-Conference of International Institute of Informatics and Systemics (IIIS, http://www.iiis.org/)”. The cumulative number of participating students from author’s program in the “World Multi-

Conferences of IIIS” was 74 from 2002 to 2021. The topics of presentation in the spring conference in 2021 were as follows:

1) Behavior of Cell on Micro Ridge Pattern after Continuous Stimulation of Tangential Force.
2) Effect of Contact between Myoblasts on Making Orientation of Cells under Shear Flow Field.
3) Effect of Shape of Cell on Dielectrophoretic Movement in Flow Channel.
4) Effect of Cell Type on Behavior of Cell under Shear Flow Field Before and After Division.
5) Effect of Activity of Cell on Division under Shear Flow Field.
6) Tracking of Deformation of Cell during Passing through Micro Gap.
7) Effect of Shape of Cell on Movement over Micro Groove in Flow Channel.
8) Experiment of Music Therapy Conducted at a Classical Music Recital: Measurement of Pulse Wave, Blood Pressure and Cardiac Orientation.
9) Experiment of Music Therapy Conducted at a Classical Music Recital: Measurement of Saliva Amylase, Hand Sweat and Muscle Hardness.
10) Construction of a Music Database for Earphone Hearing Loss Prevention and Music Therapy.
11) Basic Research on Music Therapy: Proposal on Timbre Comparison Experiment Method.
12) Earphone Hearing Loss: Discussion of Accuracy of Ear Age Conversion Method.

3. Results

Distributions of answers of students for each question are shown in Figures 1-8, respectively. At the time of answering the question, many students only follow the rules required by the government for public health purposes and do not check the results published by scientists. Many students tend to rely on statistical results. Many students lacked the pursuit of scientific causality.

Several kinds of vaccination have been started in the world. A high percentage of effectiveness is shown for each kind of vaccine. Neutralizing antibodies are expected to be produced after every vaccination (Figure 1). There are individual differences. Most vaccinations are rehearsals for infection. Antibodies may be produced faster after the rehearsal. The probability of infection is statistically reduced. Before invasion, virus can be moved from person to person during asymptomatic infections. Side reactions may occur: allergic reactions, fever, etc. Japanese students do not believe in the long-term effectiveness of the vaccines. The effect might change against mutant viruses. Vaccination is fact, while the results of test might have errors.

While every answer appears to follow precautions for COVID-19, no answer can guarantee that someone is virus-free. Because the virus moves from person to person, “without facing others” is preferred (Figure 2). There are several patients who are asymptomatic. While many students (especially in Thailand) follow the rule of masking, the virus can pass through surgical masks. The results of PCR tests depend on the timing and the sampling. Some medications mask the symptoms. A vaccine has several points for discussion: the efficacy to the virus, the acquisition rate of antibodies, and the duration of immunity. More information is necessary on several points about the patients: the recurrence, and after-effects.

Many students expect the mask to be a barrier against the virus (Figure 3). To stop the virus with a size smaller than 0.1 μm, a mask with a smaller pore size is necessary. Keeping humidity in the oral cavity helps the immune capacity. Most students understand that the droplets can be captured by the mask. The virus can move from your hand to your oral cavity by direct touch.

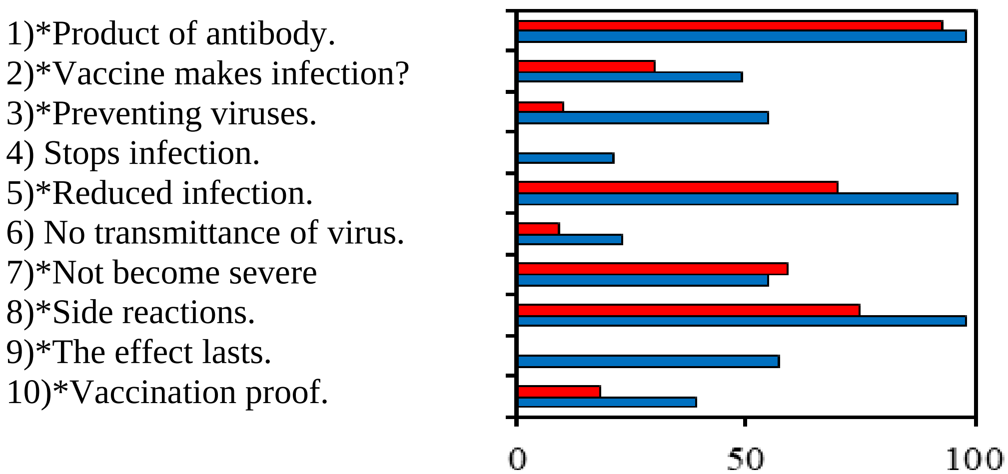

Figure 1: Effect of vaccine (%) of “True”: red, Japanese (number of samples, 56); blue, Thai (51): *by microbiological considerations.

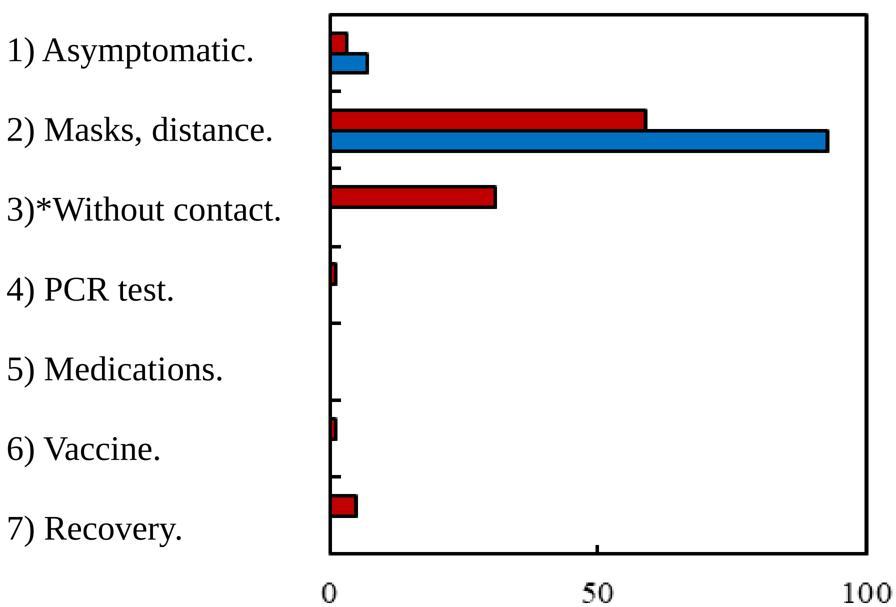

Figure 2: Select your behavior in the past two weeks to be “free of COVID-19 infection” (%): red, Japanese (56); blue, Thai (51): *by microbiological considerations.

We have several social rules recommended to prevent infection in Japan. Students follow the rules: hand-washing, ventilation, and distancing (Figure 4). We have few reports about infection in the crowded quiet space of public transportation. Virus can get into the oral cavity during eating with chatting. Ventilation is important during chatting.

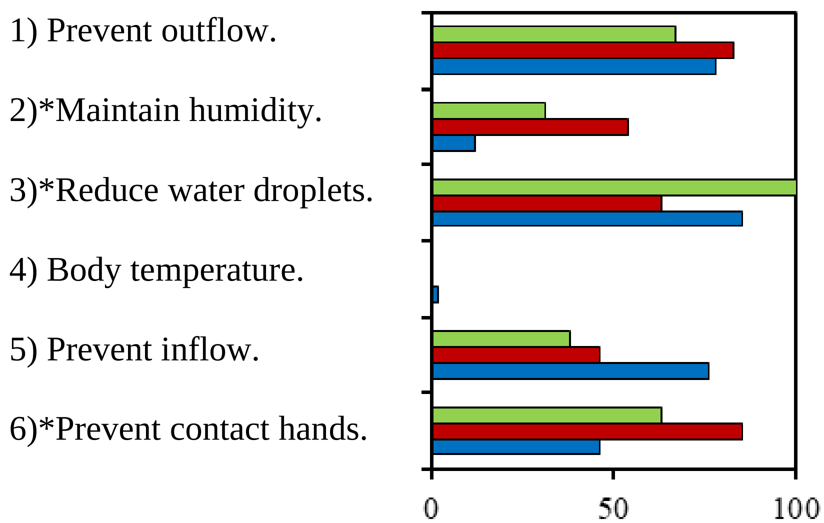

Figure 3: Select three effects of everyday-mask on COVID-19 (%): green, Japanese graduate (16); red, Japanese undergraduate (80); blue, Thai undergraduate (41): *by microbiological considerations..

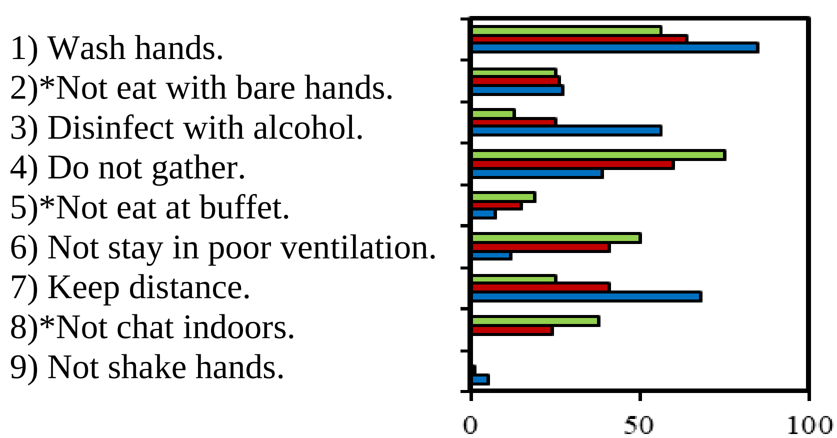

Figure 4: Choose three answers related to COVID-19 as a method to directly reduce your chances of infection (%): green, Japanese graduate (16); red, Japanese undergraduate (80); blue, Thai undergraduate (41): *by microbiological considerations.

Many students agree to the rule of distancing (Figure 5). Making barrier against droplets that contain the virus is effective to directly reduce the probability of the movement of COVID-19 virus from yourself to others. Japanese students follow the procedure of disinfection with alcohol. Both touching and gathering in groups do not cause infection without the inhalation route into the body.

The risk of infection during the test procedure is low, because the test is conducted under a specially controlled manner to prevent infection. In Japan, the cluster tracking is the first choice ((3) in Figure 6). Vaccination is a definite indication of virus prevention, so that vaccination can be a better proof than a PCR test.

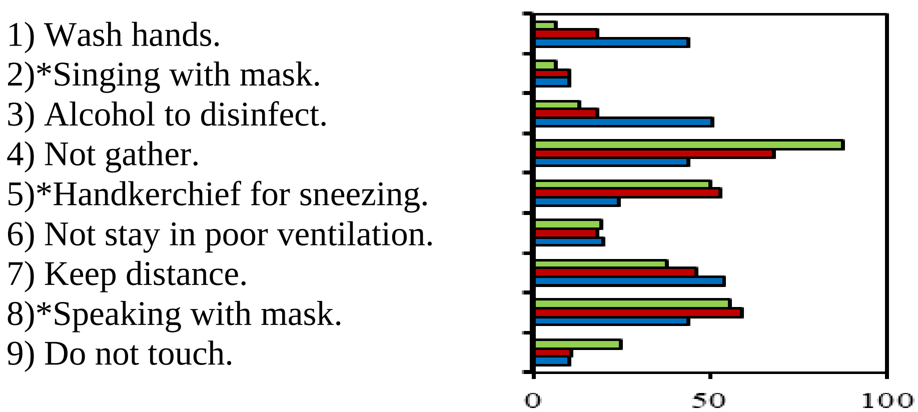

Figure 5: Choose three answers to directly reduce the probability of the movement of COVID-19 virus from yourself to others (%): green, Japanese graduate (16); red, Japanese undergraduate (80); blue, Thai undergraduate (41): *by microbiological considerations.

3.1. Topic Selection

Popular topics to students were as follows: “Automatic generation of vaccine”, “Diagnostics without facing the patient”, “Prediction of infection”, “Telemedicine”, and “Medical robot” (Figure 7).

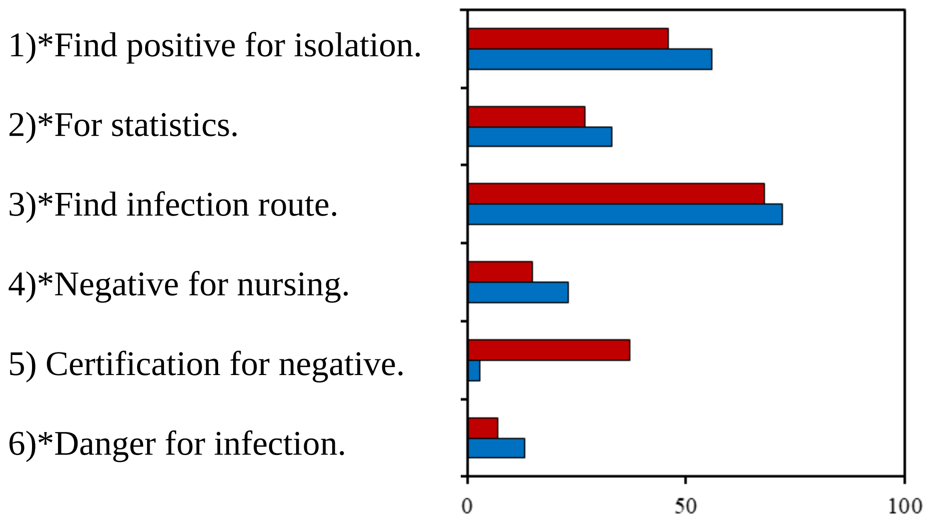

Figure 6: Which is the effect of a virus test? Select two choices (%): red, Japanese (80); blue, Thai (29): *by microbiological considerations.

3.2. Your Proposal

Many topics proposed by students were related to tests for virus detection (Figures 7 & 8). Minimized artificial organs were also popular to students. Some students proposed innovative ideas related to their multidisciplinary background. Many problems related to biology can be studied in the field of informatics with the big data of genomics. Examples of ideas proposed by students are as follows:

1) Sport-able face mask
2) Self-cleaning sanitary mask
3) Thermometer face mask
4) Face shield that detects the presence of virus
5) Chameleon headband for signal when a person has an infection
6) Remote wristband for virus sensor
7) Alert for COVID-19 in the environment
8) UVC-254 toilet

9) Scanning virus screen
10) Smart bus disinfection-door
11) Mask sterilization machine
12) Hand sanitizer bracelet
13) Disinfection spray bracelet
14) Disinfection gloves with thermometer
15) Stanchions sheet cover changing machine instead of disinfection
16) Dental robot
17) Telemedicine robots
18) Portable artificial lung
19) Smart virus protector for lungs
20) Artificial epithelial stem cells for organs
21) Fluid remover from the lungs
22) Health screening program in one step with artificial intelligence
23) Blood-testing robot
24) Delivery drone

3.3. Presentation in Multidisciplinary Conference

The annual conference of IIIS includes participants from a large number of countries: from 27 to 52. The number is rather large compared with the other international conferences on specialized fields. It is a good stimulus for young students to join in a multi-disciplinary society. The IMCIC (International Multi-Conference on Complexity, Informatics and Cybernetics) gives a chance for each participant to experience a multidisciplinary society and a cross-cultural society, simultaneously (Hashimoto, 2015).

Students enjoy a variety of research activities in the interdisciplinary field of biomedical engineering: nano /microsystems, cellular mechanics, biomechanics, biomaterials, bio-simulation, medical robotics, medical systems, biomedical informatics, bio-control engineering, bio-measurement and biomimetics

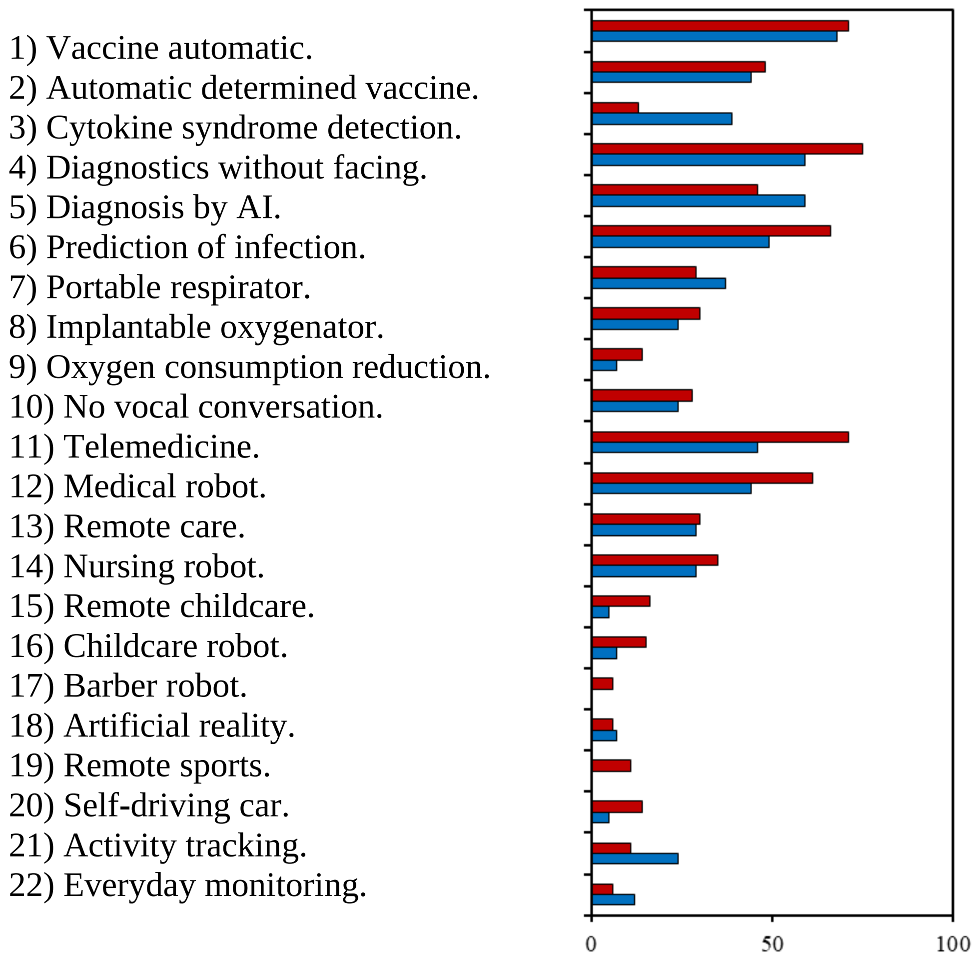

Figure 7: Choose multiple answers from the following future technologies related to COVID-19 that you would like to realize (%): red, Japanese (80); blue, Thai (41).

4. Discussion

Students in the Biomedical Engineering Department are using the clean room for micro -machining. They also learn about cell culture techniques. They are familiar with the clean space and sterilization. With interdisciplinary learning, students should not blindly follow the rules on COVID-19, but understand the purpose of the rules. Active contributions to society will lead students to their future work.

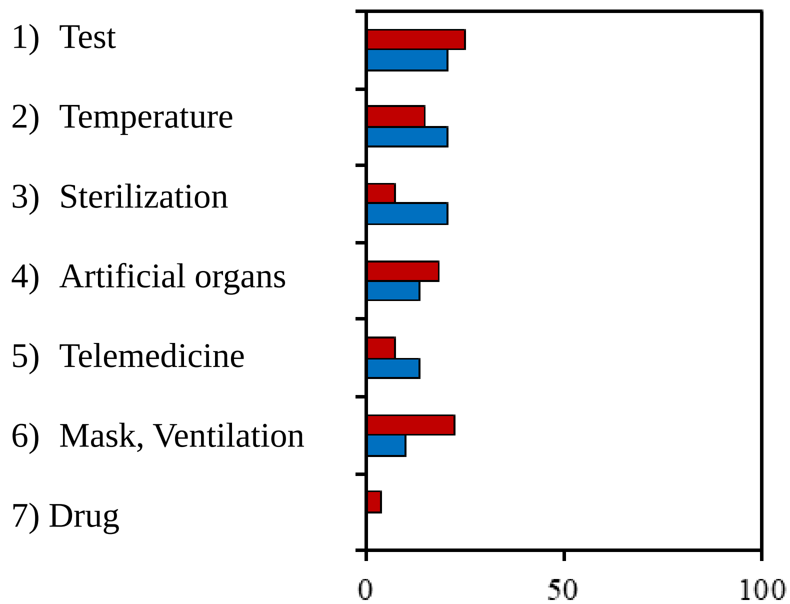

Figure 8: Category of topics proposed by students (%): red, Japanese (80); blue, Thai (29).

As a particle, the dimension of the virus is as large as a particle of cigarette smoke (Hashimoto, 2020a). They will both pass through a fine filter. Adsorption is also available to trap the virus. Once released into space, the virus continues to drift like cigarette smoke. It is not easy to remove by ventilation systems. A mask is effective reducing the amount of virus released from a human. On-time sensitive detection of viruses is expected. Animals can sniff viruses with the nose. When you are infected by COVID-19, chatting is similar to smoking. Do you blow cigarette smoke toward your neighbors at a short distance? You might refrain from smoking during eating. The image of cigarette smoke will help you to refrain from making close contact with a person in everyday life.

The author allows students to be relaxed during class except when chatting and smoking. It is a general rule that smoking is prohibited in the classroom. Why is chatting prohibited? Both of these actions affect your neighbors. Receiving smoke passively causes a risk of carcinogenesis. Chatting interferes with the concentration of your neighbors. These rules can also control infection. Prohibiting chatting has the effect of reducing the amount of virus released from the respiratory tract of an asymptomatic patient during class.

The number of people infected with COVID-19 in Japan is higher than that in the other East Asian countries, according to COVID-19 Dashboard by the Center for Systems Science and Engineering at Johns Hopkins University (https://gisanddata.maps.arcgis.com/apps/opsdashboard/index.html#/bda7594740fd40299423467b48e9ecf6). In Japan, there has been a warning about an increase in suicide, but the increase is not so great (www.nippon.com/ja/japan-data/h00635/). The overall death toll is declining (https://tanoshikuikiyo.com/strange-mortality-has-begun-to-be-reported/). It is considered that control of COVID-19 has the effect of reducing general infectious diseases. Flu is also decreasing, according to the World Health Organization (https://www.who.int/toolkits/flunet).

The virus continues to mutate. There is no almighty permanent antibody. Vaccines cannot solve everything. The role of medical devices is important: respirators, diagnostic equipment, medical equipment, and artificial organs. The sequela of COVID-19 are related to thrombus formation. Thrombus formation is an important research topic in blood circulatory assist devices (Hashimoto, 2018).

Engineered systems that physically and mentally support daily life form a society resistant to infectious diseases. It is not easy to complete those complex systems only by studying in specialized fields (Hashimoto, 2019). Fusion of academic fields realizes innovation. Infectious disease control may promote the formation of a barrier between people. The inter-disciplinarian shall make bridges between disciplines to break through barriers (Hashimoto, 2020a).

Sterilization is a big issue for medical equipment. Every object with the virus will be sterilized and safely disposed of. Syringes used for infectious diseases are disposable. Waste management is important for the sustainable society. Every material should be recycled. For disposable items, attention should be paid to the materials. The disposable mask can lead to the environmental pollution. Plastics are not decomposed immediately. They will remain in the environment for a long time. Microplastics cause a problem in the global environment. With a view of degradation, plastics are different from radioactive materials, which have a half-life of radioactivity.

Repeating the same thing as a long-term strategy is emotionally difficult for some people to accept. Concentrated items are preferable (Hashimoto, 2020b). “Do not inhale virus into the respiratory system.” “Reduce the amount of discharge of virus (chatting is prohibited without mask).” It is easier to motivate people to prepare for new threats (mutant virus). Is this time a practice for the next pandemic? Will the next wave be by mutant strains (increased infectivity?)? The flu virus has more variation of mutation.

Vaccination trains the body for infection. Some treatments use the antibody itself. Additives in the vaccine fluid can cause accidents. Allergy to pollen should be carefully examined related to individuality in the immune response. It takes time to establish herd immunity. In Japan, vaccination is no longer mandatory due to the history of serious adverse reactions to vaccines (https://medicalnote.jp/contents/151216-000015-QOVWJX). The only way to maintain the health care system of society is to reduce the number of patients or reduce the number of people who depend on health care. Individual declaration affidavits (wills) are also useful when it comes to deterioration of health conditions and funerals.

5. Conclusions

In the courses of Biomedical Engineering, students answered several questions related to COVID-19: Japanese undergraduate students in “Biomechanics”, master-course students in “Advanced course of biomechanics” in Kogakuin University, and Thai undergraduate students in “Biomechanics” in Mahidol University in 2020. At the time of answering the question, many students tended to rely on statistical results. Many students lacked the pursuit of scientific causality. Many topics proposed by students were related to testing for virus detection. Some students proposed innovative ideas related to their multidisciplinary background. The annual conference of IIIS included participants from a large number of countries. The IMCIC (International Multi-Conference on Complexity, Informatics and Cybernetics) gave a chance for each participant to experience a multidisciplinary society and a cross-cultural society, simultaneously. Students enjoyed a variety of research activities in the interdisciplinary field of biomedical engineering: nano /microsystems, cellular mechanics, biomechanics, biomaterials, bio-simulation, medical robotics, medical systems, biomedical informatics, bio-control engineering, bio-measurement and biomimetics. After taking the course of “Biomedical Engineering”, students have realized that engineering is related to many special fields of study. As a case study, students have studied COVID-19 and found the key point related to the pandemic: the main pathway for SARS-CoV-2 is hypothesized to be via the air between the human respiratory systems. How can we communicate with each other beyond the barriers to prevent infection? The multidisciplinary learning inspired students to find innovative topics for a new society. Many global problems are waiting for a multi-disciplinarian.

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