Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

Elsevier hereby grants permission to make all its COVID-19-related research that is available on the COVID-19 resource centre - including this research content - immediately available in PubMed Central and other publicly funded repositories, such as the WHO COVID database with rights for unrestricted research re-use and analyses in any form or by any means with acknowledgement of the original source. These permissions are granted for free by Elsevier for as long as the COVID-19 resource centre remains active.
Research Activities in Materials Science and Engineering with Academic-Industrial Alliances during the COVID-19 Pandemic

Hideyuki Kanematsu\textsuperscript{a*}, Dana M. Barry\textsuperscript{b}, Nobuyuki Ogawa\textsuperscript{c}, Shin-nosuke Suzuki\textsuperscript{d}, Kuniaki Yajima\textsuperscript{e}, Katsuko T. Nakahira\textsuperscript{f}, Tatsuya Shirai\textsuperscript{a}, Masashi Kawaguchi\textsuperscript{a}, Takehito Kato\textsuperscript{d}, Michiko Yoshitake\textsuperscript{g}

\textsuperscript{a}National Institute of Technology (KOSEN), Suzuka College, Shiroko-cho, Suzuka, Mie 510-0294, Japan
\textsuperscript{b}Clarkson University/SUNY Canton, Potsdam/Canton, New York State, the United States of America
\textsuperscript{c}National Institute of Technology (KOSEN), Gifu College, Kami-Makuwa, Motosu, Gifu, 501-0495, Japan
\textsuperscript{d}National Institute of Technology (KOSEN), 624-1, Numa, Tsuyama, Okayama 708-8509, Japan
\textsuperscript{e}National Institute of Technology (KOSEN), Sendai College, 4-16-1, Ayashi Chuou, Aoba-ku, Sendai, Miyagi 989-3128, Japan
\textsuperscript{f}Nagaoka University of Technology, 1603-1, Kami-Tomioka, Nagaoka, Niigata 940-2188, Japan
\textsuperscript{g}National Institute for Materials Science, 1-1, Namiki, Tsukuba, Ibaraki 305-0044, Japan

Abstract

During the COVID 19 pandemic, the importance of global academia-industrial alliances has increased. It is hoped that the alliances will help us to solve the current problems caused by the pandemic. In this paper, we introduce the application of IT tools and communication skills utilized in a special educational project for an academia-industrial collaboration. Some concrete examples from 2020 are provided from the viewpoint of the national alliance project in Japan. A discussion is included that describes the plans available to increase and strengthen the national project in the future.

© 2021 The Authors. Published by Elsevier B.V.
This is an open access article under the CC BY-NC-ND license (https://creativecommons.org/licenses/by-nc-nd/4.0)
Peer-review under responsibility of the scientific committee of KES International.

Keywords: academia-industrial alliances; GEAR 5.0; smart society; IT tools; distance research; half distance research; complete distance research
1. INTRODUCTION

COVID-19 has changed the social system everywhere in the world [1]. Japan happened to establish the goal for their fifth Basic Program for Science and Technology. This country has an Outline for Basic Science and Technology, the fundamental guideline for their science and technology policy. It is for the realization of a smart society, where every aspect in their society (including science and technology, education, production, business, daily lives, etc.) would utilize information technology, cyberspace and virtual reality [2]. Barry and Kanematsu have investigated and carried out educational activities in virtual reality for 20 years. Even at the beginning of their collaboration, both continued their own activities individually while being separated geographically. They needed the IT technology at that time. This long collaboration taught Barry and Kanematsu many techniques and helped them accumulate rewarding experiences as well as technological skills [3]-[12]. Many years went by and then the COVID-19 pandemic occurred at the end of 2019. Like other countries’ educational organizations, the authors had difficulty continuing their collaborations. However, our accumulated past experiences turned out to be very helpful.

In this paper, we describe the background information for the academic-industrial alliance in Japanese society and academia. We also introduce KOSEN’s new research project for the alliances (GEAR 5.0) and the concrete unique system. Then specific examples are mentioned for the alliance in the case of Kanematsu’s research activities. The change of the situation for the alliance before and with a COVID-19 society is presented. Finally, the effect of IT tools on the alliance is discussed.

2. THE IMPORTANCE OF ACADEMIA-INDUSTRIAL ALLIANCE IN MODERN SOCIETIES

Academic-industrial Alliances have increased their importance in modern societies all over the world. The tendency has been accelerated with the change of societies and as a result, the mission of higher education seems to be changed inevitably[13]-[22].

On the industrial side, we could mention companies’ change of policies. One of them is driven by the tendency of open innovation. The open innovation is defined as the innovation way where not only a company, but also other companies, universities, entrepreneurs, and communities collaborate with each other to produce products and systems, leading to the successful development. The general form is shown in Fig.1 schematically.

Open innovation has recently been adopted by many companies. The reason could be attributed to that the companies must correspond to the rapidly changing societies. They have to achieve the companies’ goals and purposes effectively. As a result, they tend to adopt the open innovation strategy. For the efficiency is much higher than that by the previous strategy. Usually, the tendency is expressed as the phrase, “Selection and Concentration”. Setting such an alliance for any projects makes companies concentrate on their strong point. It must be true also for academia. They can concentrate on education and cultivation of human resources. When academia and industries collaborate with each other, companies could use the knowledge source and fundamental ideas to develop their products. On the other hand, academia could ask companies to help cultivate younger persons. Such a collaboration
between academia and industries brings the collaborative education on an educational side. The “on the job training” will come true relatively easily. The form is shown in Fig. 2 schematically. In such an alliance between academia and industries under the open innovation policy, both sides could make their strong points, respectively. On the side of academia, schools could provide companies with their fundamental knowledge, seeds for their research ideas, etc. On the other hand, companies could give schools the opportunities for patenting, capability of production and being in business. And companies could cooperate with academia to cultivate students, giving them the chance for internships and on the job training.

3. GEAR 5.0 Project and the meaning in Japanese society – KOSEN Research Project

From the background described above, KOSEN (National Institute of Technology, Japan) began the new national project entitled GEAR 5.0 in May of 2020. It is supported financially by the Ministry of Education, Culture, Sports, and Technology, Japan. This project was established to cultivate young promising persons (students, young faculties/teachers, companies’ engineers, researchers) through the research project, so that they can be active in the future smart society. To achieve the purpose, some topics were chosen and the virtual research centers for each research topic would have been established all over Japan, just like the networks among KOSENs, since KOSEN (Colleges of National Institute of Technology) are scattered all over the Japanese islands. Originally, five research centers would have been built. However, due to the lack of a national
budget, two of the originally planned five centers were established first. The other centers would be established year by year within the original four-year plans. The two centers were chosen for materials science and nursing care sciences. Each center has the core college as its headquarters, respectively. As for a materials science center, Suzuka College (Kanematsu’s working place) was chosen. The 4 designated KOSENs and 9 coalition KOSENs were chosen to collaborate with each other.

Fig.3 shows the concept of GEAR 5.0 Materials UNIT. As described above already, the total 51 colleges of the National Institute of Technology (KOSEN) are scattered all over Japan’s country. They are classified into five blocks. The colleges located in Hokkaido and Tohoku region belong to the first block. The colleges in the area around Tokyo, Kanto, and Koshinetsu regions belong to the second block. The colleges in Kinki, Tokai and Hokuriku (including Suzuka College) belong to the third block. The colleges in Shikoku and Chugoku belong to the fourth block. And colleges in Kyushu Island and Okinawa Islands belong to the fifth block. The headquarters for the materials science unit was set in Suzuka. Other designated colleges were chosen from the other four blocks. That was the original rule. As a result, five colleges collaborate on behalf of each block to achieve the mission.

The reason why Suzuka College was chosen as headquarters could be attributed to two reasons. One of them is that Suzuka College had a unique academia-industrial laboratory system before the GEAR Project started. It is called Academia-industrial alliance laboratory system, tentatively. In the system, a company provides the college a certain amount of research money (according to the rule in the Suzuka College case). The college allows a company to establish a laboratory where many faculties and students collaborate with the company under a certain topic according to the company’s plan. Then the company can dispatch some staffers as visiting professors, etc. This system could give the credece to the company because many researchers could try to solve the company’s problems with them in a team. The company could expect a certain achievement absolutely, being different that there have been many contracts between the company and just one researcher in many cases. On the other hand, the college could have the opportunities to cultivate students as on-the-job training and as an internship opportunity. Therefore, the company and college could have the mutual merits at the same time, as if Fig.2 shows. The system was not devised by Suzuka College. However, it has prevailed in Japanese universities. Suzuka college was the first among KOSEN. Being different from universities, KOSEN is oriented more to education. However, KOSEN also needs high level research activities to cultivate the innovators in the world for the future. The headquarters evaluated the system of Suzuka College very highly.

The second reason could be attributed to the abundant supply of analytical apparatus for research and development on materials science in Suzuka College. The faculty have collaborated with each other to introduce those facilities for 50 years. Now they have FIB-SEM, TEM, SEM-EDX, XRD, Raman spectroscopy, FT-IR, Laser Microscopy, XPS, etc. Taking the size of the college (the number of students:1000, the number of faculties: 80, the number of departments: 5) into considerations, the enhancement and plentitude are high. The headquarters expects that the ally colleges could share the versatile apparatus and others belonging to other colleges virtually to pursue their collaborative research projects. One year has already passed and the materials science unit has achieved a lot well beyond their expectation.

The final purpose of the project is the human cultivation through high level research activities and the societal implementation between academia and industries. We wish that the research project will soon actively drive the Japanese society. It is wished that the driving force to promote Japanese industries and society further would be driven by KOSEN. Since KOSEN’s original mission is to cultivate industrial youngsters with high level disciplines and practical applicability through academia-industrial alliances, the project must be very suitable for KOSEN.

4. Concrete Examples in 2020 – Kanematsu’s Case

According to the concept, Kanematsu’s Laboratory became active and in 2020, Kanematsu’s Laboratory had contracts with five companies, individually. The Laboratory was composed of only one researcher (Dr. Kanematsu) and seven students. It means that the laboratory was not so big. Being compared with the average size of laboratories in Japanese higher education organizations, Kanematsu’s Laboratory is smaller than the average size. However, the five annual contracts with five companies are more than the average one. Kanematsu’s Laboratory has dealt with the infection capability spreading through materials between humans-to-humans. However, companies collaborating with Kanematsu’s Laboratory were versatile.
Company A was well known for producing apparatus that was mainly used in the plating fields. Company B produces polymeric substances. Company C is a surface finishing company. Company D is an electronic company. Company E is a production company of chemicals and medicine.

These five contracts were carried out in 2020, during the COVID-19 pandemic. Therefore, the movement of research members between Kanematsu’s Laboratory and each counter partner was sometimes completely restricted. Therefore, the research collaboration had to be supported by IT tools, such as internet related programs, facilities, etc.

Such a collaboration could be classified into three types.

1. Non-distance research.
   The concept means that research works were pursued only on one side. In fact, the company asked the laboratory on the academic side to carry out the experiments in a unilateral way. Even though the virtual meeting was held sometimes for the mutual understanding in the internet, experiments were not carried out on both sides.

2. Half distance research.
   The information, research background, experimental method, experimental results and discussion are always shared very often, using virtual meeting application tools. In addition, the experiments were carried out on both sides, and the synchronized information could be shared with a virtual meeting.

3. Complete distance research.
   All components for half distance research activities should be included for this concept. In addition, the apparatus and facilities could be operated virtually from the other persons from a distance. This time, the case did not work.

5. A Trial to complete distance research project.
   As described above, the utilization of IT has been restricted to half distance research projects so far. However, the improvement could be realized and accelerated by the introduction of complete distance research projects. Here we summarize the difference among the three distance research projects in Table 1. Due to the existence of classified contracts among them, the contents and the names of the companies are kept anonymous in this paper.

| Company’s field                | Type of collaboration | Satisfaction level | Next Step  |
|-------------------------------|-----------------------|--------------------|------------|
| Company A: Plating apparatus | Half distance research | A (Very satisfied) | Positive   |
| Company B: Polymeric materials| Half distance research | A (Very satisfied) | Positive   |
| Company C: Surface finishing  | Half distance research | A (Very satisfied) | hold       |
| Company D: electronics        | Non distance research  | B (Neutral)        | Not decided|
| Company E: chemical company   | Non distance research  | C (Unsatisfied)    | Negative   |

As Table 1 shows, company A, B and C adapted half-distance research and carried out the experiments on both sides. The information and results were shared with each other, using virtual meetings, email messages, etc. However, the information (experimental results, experimental methods, background, etc.) were very often exchanged mutually. Therefore, the current situation and the proceedings on one side could be experienced on the other side almost simultaneously. On the other hand, Company D and E had non-distance research type collaboration. Table 1 shows very clearly and simply how very important the mutual communication and the interactivity are between academia and industries. Unfortunately, we didn’t have any complete distance research
case. However, if we could have such a research collaboration type, the interactivity would have been increased drastically and the high satisfaction level could be achieved absolutely.

4. Conclusions - For the future

In this paper, we introduced the unique research project called GEAR 5.0 and explained why KOSEN started the research project through academia-industrial collaborations. Then we mentioned concrete examples for the alliance in the case of Kanematsu’s research activities. The satisfaction level for the collaboration seemed to be related to the interactivity and the following feeling of unity. In this paper, the mutual interactivity between academia and industry was kept by using the half distance research method. However, we have to realize the collaboration through complete distance research, so that the interactivity and the efficiency could be increased much more.

Acknowledgements

This work was supported by JSPS KAKENHI (Grants-in-Aid for Scientific Research from Japan Society for the Promotion of Science, Grant Number 19K12246 and 21H00914. A part of this work was supported by GEAR 5.0 Project of the National Institute of Technology (KOSEN) in Japan. And finally, we appreciate Feepik for us to use some figures freely.

References

[1] Magda Borkowska & James Laurence (2021) Coming together or coming apart? Changes in social cohesion during the Covid-19 pandemic in England, European Societies, 23:sup1, S618-S636,
[2] Japan Cabinet Office: Report on the 5th science and technology basic plan, https://www8.cao.go.jp/estp/kihonkeikaku5bASICplan_en.pdf, 2015
[3] Barry, D.; Kanematsu, H. Workshops in creative education for students and teachers in the United States and Japan. In Proceedings of 2007 37th annual frontiers in education conference - global engineering: knowledge without borders, opportunities without passports, oct.
[4] Barry, D., M.; Kanematsu, H.; Fukumura, Y.; Ogawa, N.; Okuda, A.; Taguchi, R.; Nagai, H. Problem Based Learning Experiences in Metaverse and the Differences between Students in the US and Japan. International Session Proceedings, 2009 JSEE Annual Conference - International Cooperation in Engineering Education-2009, 72-75.
[5] Barry, D.M.; Kanematsu, H. Develop Critical Thinking Skills, Solve Mystery, Learn Science (CD Audio Book); Tate Publishing & Enterprises: Oklahoma City, USA, 2007.
[6] Barry, D.M.; Kanematsu, H. Develop Critical Thinking Skills, Solve A Mystery, Learn Science; Tate Publishing & Enterprises: Oklahoma, USA, 2007.
[7] Barry, D.M.; Kanematsu, H. International Program Promotes Creative Thinking in Science. The Education Resources Information Center (ERIC) online paper, The Institute of Education Science, The US Department of Education 2008, ED 500317.
[8] Barry, D.M.; Kanematsu, H. International Collaboration: Creative Engineering Design Program Between the U.S. and Japan. In Innovation 2010, Aung, W., Moscinski, J., Uhomoibhi, J., Wang, W.-C., Eds. International Network for Engineering Education and Research (iNEER): Washington, USA, 2010; pp. 163-176.
[9] Barry, D.M.; Kanematsu, H. Virtual House of the Future During the Global Warming Era. In STEM and ICT Education in Intelligent Environments, Kanematsu, H., Barry, D.M., Eds. Springer International Publishing: Switzerland, 2016; 10.1007/978-3-319-19234-5pp. 173-179.
[10] Barry, D.M.; Kanematsu, H. Mars Simulation Mission. In STEM and ICT Education in Intelligent Environments, Kanematsu, H., Ed. Springer International Publishing,: Switzerland, 2016; 10.1007/978-3-319-19234-5pp. 153-165.
[11] Barry, D.M.; Kanematsu, H.; Lawson, M.; Nakahira, K.; Ogawa, N. Virtual STEM activity for renewable energy. *Procedia Computer Science* 2017, 112, 946-955, doi:10.1016/j.procs.2017.08.130.

[12] Kanematsu, H.; Barry, D.M. *STEM and ICT Education in Intelligent Environments*; Springer: 2016.