2021 ASEE ANNUAL CONFERENCE
Virtual Meeting | July 26–29, 2021 | Pacific Daylight Time
Paper ID #34165

Revolutionize Ph.D. Training in Academia-industry Collaboration

Shiuan-Huey Yen, Institute of Engineering Education Taiwan

I'm working as Project Specialist of Institute of Engineering Education Taiwan (IEET) and my BAU is about MOE Industry-Academia Cooperative Project. Graduated from National Taiwan University and received Master's degree in Linguistics.

Jessica Fan, Institute of Engineering Education Taiwan

Ms. Jessica Fan is currently the Accounting Manager and Project Manager of Institute of Engineering Education Taiwan (IEET). Her primary responsibilities are to oversee accountant and Ministry of Education Academia-Cooperative PhD Project.

Dr. Mandy Liu, Institute of Engineering Education Taiwan

Dr. Liu is currently the Deputy Executive Director of the Accreditation Council and Office Director of Institute of Engineering Education Taiwan (IEET), an accreditation agency for engineering education. Her primary responsibilities are to oversee day-to-day operation of the accreditation and international activities of the Institute. Prior to her current position, Dr. Liu worked as a research associate for the Association of American Medical Colleges (AAMC) in Washington DC, USA, where she conducted research in the area of organization and management studies of medical schools. Dr. Liu received her doctorate in higher education policy and management from Claremont Graduate University in the USA.

Prof. Liang-Jenq Leu, Institute of Engineering Education Taiwan

Dr. Liang-Jenq Leu is Professor and former Chairman of the Department of Civil Engineering at the National Taiwan University. He serves as President of Taiwan Construction Research Institute and Secretary General and Executive Director of the Accreditation Council of the Institute of Engineering Education Taiwan (IEET). He is the Subject Editor of the Journal of the Chinese Institute of Engineers (a SCI journal). He served as the President of the Chinese Institute of Civil and Hydraulic Engineering (CICHE) during 2014-2017 and the President of the Chinese Society of Structural Engineering during 2016-2017. Dr. Leu earned his Bachelor's and Master's degrees from the Department of Civil Engineering of National Taiwan University in 1987 and 1989, respectively. He joined the faculty of National Taiwan University shortly after receiving his PhD from Cornell University in 1994. His area of research includes optimal design of structures, structural health monitoring, earthquake resistant design, and simulation of architectural physics for green buildings.

Revolutionize PhD Training in Industry-Academia Collaboration

For the past decade, the PhD enrollment rate in Taiwan has dropped sharply. Statistics from the Ministry of Education (MOE) showed decreased PhD enrollment in the past decade. Although engineering has the highest number of PhD students among all disciplines, the decline was also observed from 11,955 to 7,849. Meanwhile, the dropout rate among PhD students is on the rise -- making the case even worse. Most of the remaining PhD students have their eyes on entering professorships instead of the industry despite the limited position. To reverse the above scenarios and enhance the industry’s research capacity, and hence the national economy, MOE has launched the Industry-Academia Cooperative PhD (IAPhD) project in 2014. The IAPhD Project is to bridge academia and industry into a win-win situation, and better yet, a three-win, including the PhD graduates by supporting PhD graduates with stipends throughout their university training. In return, the PhD students are engaged in developing their dissertation with a heavily industry-centered orientation and contributing to the advancement of technology for their companies. Outcomes for students are expected to be different from their peers who are on the traditional scholarship track. The current study investigates the implementation and results of the IAPhD Project by analyzing the students’ performance and the employment status of the 22 graduates supported by the IAPhD Project. Such analyses shall shed light on the Project’s policy aspects and help the MOE gather evidence of public resources’ effectiveness.

Introduction

Having high-level talent has always played a key role in economic progress. The top performers in the Bloomberg Innovation Index, including Japan, the U.S., and Taiwan [1], have also placed value on doctoral education. Japan has revealed its vision to improve career prospects for young researchers. The U.S. issued guidelines to support University-Industry Cooperation (UIC). In Taiwan, universities receive funds for research and development (R&D) management. However, cultivation of doctoral-level talents across the country has recently faced several challenges, including a downward trend in doctoral student enrollment [2]-[3], a high dropout rate in doctoral programs [4]-[5], and delayed graduation among the doctoral students [6]-[7]. In addition, most doctoral students choose to stay in academia, while those who decide to leave faced difficulties in career transition [8]-[10].

UIC drives development in technology and business [11] and has been used in R&D for decades. To stimulate R&D activities and bridge the above gap, MOE launched the Industry-Academia Cooperative PhD (IAPhD) Project in 2014 [12] with the concept of UIC in mind. To understand the outcomes and impacts of the IAPhD supported by the IAPhD Project in relation to UIC models and make policy recommendations, this study used direct and indirect measures to examine the employment status of 22 alumni. The unique and successful UIC models in Denmark, France, Japan, and the United States are discussed to shed light on future improvement of the UIC model adopted in the IAPhD Project.

Regional and national R&D in high-level talent training in Japan

Japan's UIC supporting initiatives reflected the importance of small firms in R&D. The country's UICs did not develop as rapidly as those of the U.S. and other European countries, possibly due to the lack of funding for small firms with R&D energy [13]-[14]. Since small firms usually face resource constraints [15], innovation initiatives constantly monitor their performance to provide the necessary support [16]. It is suggested that small firms benefit from UIC regarding its characteristics related to practical goals and productization [17]. Japan has also emphasized on high-level talent training to stimulate both national and regional R&D.

The White Paper on Science and Technology [18] revealed a vision to improve the prospects for young researchers. With this vision, the Doctoral Program for World-Leading Innovative & Smart Education (WISE) was established [19]. The WISE program mainly supports students for a combined 5-year master's-PhD program through consortia among universities, public research institutions, and companies. Students receive an annual stipend of US$5,500 from the consortia for up to 7 years. The program stimulates collaboration between research laboratories of different universities, factories, public organizations, and countries.

On the other hand, the Industrial PhD Supported by Collaboration between Academic Institutions and Industry (IPSCAI) program has been proposed [20],[21]. The program is based on the Super Collaborative Graduate School Program but focusing on local UICs. During doctoral study, students are employed and paid by participating companies. The government planned to provide financial support to participating universities and companies. Although the program is still in the planning stage, it is expected to stimulate local business development.

Japan has established programs for high-level talent training and is tracking the impact of these programs to improve the prospects for young researchers. In addition, the Japan National Institute of Science and Technology Policy (NISTP) has established the Japan Graduates Database (JGRAD) [22]. By tracking PhD human resources, Japan is constantly improving its high-level talent training programs and innovative initiatives.

Cultivating interdisciplinary skills among high-level talents in the U.S.

As universities are considered a source of advanced knowledge in science and technology (S&T), innovation initiatives in the U.S. have emphasized technology transfer. Beginning with the Bayh-Dole Act, intellectual property (IP) rights were transferred to universities. This gradually diversified the role of universities from doing research only to commercializing the research results [23]. R&D activities and patent applications have increased due to UIC [24], which also stimulates regional R&D activities [25]-[26].

For training talent in the U.S., Wang [27] addressed two projects: the Graduate Assistance in Areas of National Need (GAANN) and the Integrated Graduate Education and Research Traineeship (IGERT). The GAANN program awards scholarships to students at the institution in areas of national need. Each student receives an annual stipend of approximately US$34,000 for up to 3 years [28]. Participating institutions were required to contribute at least 25% of the awarded scholarship. Under the GAANN program, almost 50% of the students have earned their PhD or passed the qualifying examination. In this context, the average duration of study of the students ranges from 5.8 to 6.3 years [29].

The IGERT program and the NSF Research Traineeship (NRT) program were established to enhance doctoral students' interdisciplinary skills. Each student receives an annual stipend of approximately US$30,000 for up to 5 years [30]. The performance report of the IGERT program showed that 54% of the students obtain a PhD degree [31]. Their study duration was reported to be 5.2 years on average. The programs held annual competitions showcasing highlights, stories, and achievements of the awardees, which help track project implementation and facilitate the promotion of talent training.

The U.S. has established training programs for high-level talent and demonstrated a method of promoting UIC. In addition, initiatives encourage greater university and business participation in R&D by emphasizing IP protection. Similar to Japan, initiatives in the U.S. are gaining flexibility for UIC.

Industry-oriented PhD training program of Denmark

Denmark has experience with industrial PhD programs since 1970 [32]. The Danish Industrial PhD Programme is a 3-year industrially oriented PhD project. Students are employed by participating companies during doctoral study and receive an annual salary of US$66,000 and an annual government stipend of US$33,000. In addition, the government provides US$16,000 to participating companies for project-related expenses. International students in the program receive US$19,500 for travel and stay at the university [33]. So far, participating companies have seen increases in patent applications, gross profits, and factory productivity [34]. Graduates of the program received higher salaries and held higher positions in the companies compared to traditional PhDs. The program demonstrates the effect of focusing on the need of industry in UIC.

International cooperation industrial PhD program of France

The Conventions Industrielles de Formation par la Recherche (CIFRE) was established as a 3-year, industry-oriented project [35]. Students are employed by participating companies during their doctoral study and receive an annual salary of at least US$28,000 and an annual government stipend of at least US$17,000. To expand UIC opportunities, CIFRE launched an international cooperation program with Morocco in 2016. As the two countries frequently cooperate in business, CIFRE aims to strengthen overseas R&D energy. In the same year, CIFRE reported an alumni survey [36]. During doctoral study, R&D experiences in participating companies help students gain a sense of responsibility. CIFRE has helped increase the employment rate of doctoral students, and graduates have received higher gross salaries than traditional PhDs. The above successful cases provided key areas for exploring ways to improve UIC among government, universities, and industry roles within.

Industrial-Academia Cooperative PhD Project

To revitalize doctoral training in Taiwan, MOE initiated the IAPhD Project in 2014. The Project aims to provide incentives for PhD students to engage in practical industry training and career development. Students can choose to participate in a 5-year master's-PhD combined or a 4-year PhD program. Participating students spend 2 years at the university taking courses and 2 years in industry completing internships to fulfill degree requirements.

Considering the pressing needs of the industry, the Project has aligned with the 5+2 Innovative Industries Plan of the Executive Yuan [37], namely Internet of Things, Biomedical, Green Energy, Smart Machinery, Defense, High-Value Agriculture, and Circular Economy. In 2020, MOE added additional funding to establish a new pilot track which invites the industry to submit current and essential topics that fit the programs and students directly to the Project.

MOE has set up criteria for academic programs to comply to ensure the quality of the Project. The criteria are mainly related to matching funds and Key Performance Indicators (KPIs). The MOE provides students with an annual stipend of approximately US$7,000. Participating universities and their industry partners should contribute at least 50% of the scholarship funds, with at least 70% of the matching funds from industry partners. The MOE also provides each program with up to approximately US$30,000 in research funding per year. Industry partners should provide at least 20% of the funds. The MOE has a set of KPIs for all programs. One key indicator is establishing a full-fledged academic program or division within 3 academic years of approval to participate. The other one is the adjustment of graduation requirements away from those of the traditional degree program.

Since 2014, the MOE has approved 79 programs at 29 universities for the IAPhD Project. Currently, approximately 464 students are participating in the Project. However, an evaluation mechanism for the Project outcomes has never been established, let alone for the impact of the MOE policy. This study thus aims to fill this void.

Data collection

This study's target population is 464 doctoral students and 22 alumni participating in the Project. Information on the students was obtained from the programs' annual reports. A survey was conducted on the alumni.

Except for programs that have ceased, each participating program is required to submit an annual report at the end of the academic year. The report recorded the KPIs achieved and the level of student participation in research with partner industries, course enrollment, qualifying examination status, publications, patent applications, and R&D results.

The alumni survey form consisted of 3 sections: Basic Information, Employment Status, and Project Satisfaction. The Basic Information section collected information about the alumni's program, universities, and internship institution. The alumni's enrollment and graduation year were also recorded. In the Employment Status section, information about the alumni's first job and current job in terms of position and salary was collected. In the Project Satisfaction section, alumni are asked about their experiences with the doctoral program, career development, and suggestions for the IAPhD Project. All information is collected to provide insights and opportunities for improvement for the Project.

Results

Results of IAPhD programs' annual reports

The current study collected data from 59 approved programs at 26 universities. The results of the programs' annual reports included three main parts, achievement of KPIs, program implementation, and program feedback.

First, we examined whether each program has achieved the establishment of an academic program or division to meet the KPIs. As Figure 4.1.1 shows, 42 programs have achieved the KPIs, 11 were still in the planning process, and 16 did not achieve the KPIs.

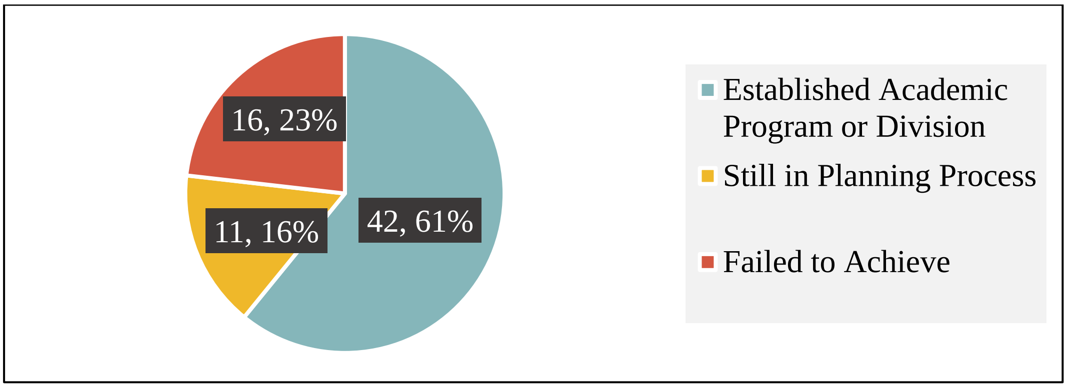


Figure 4.1.1 Proportion of Establishment of Academic Program or Industrial Division

Another important indicator is the adjustment of graduation requirements (e.g., taking into account R&D results). Most programs made adjustments to course requirements. Among the programs, 25 have adjusted graduation requirements and requirements on study period, 10 have altered graduation requirements but not requirements on study period, 10 have changed requirements on study period only, and 3 have modified course requirements only. Nevertheless, some of the programs have not reached the KPI, 6 are still in the planning process, and 5 have not yet made any adjustment (Figure 4.1.2).

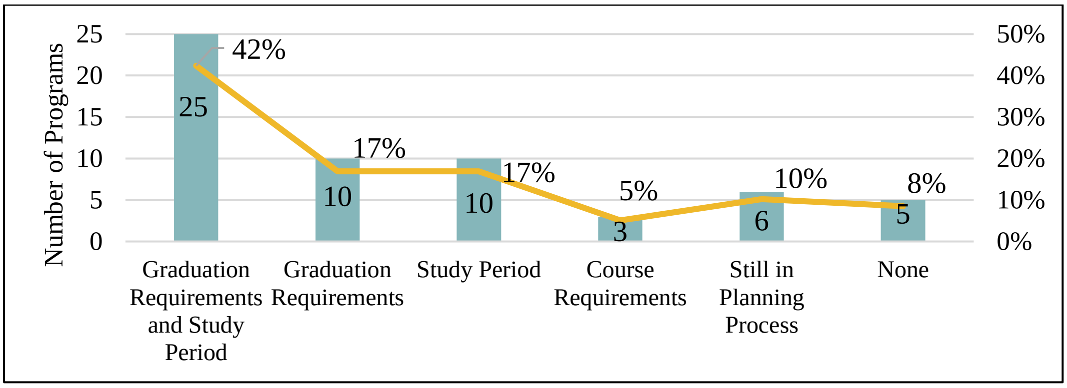


Figure 4.1.2 Programs Adjustment to Requirements

Second, program implementation is noted in the annual report in terms of highlights and outcomes. 290 industry partners supported the programs with matching funds and paid internships. The 464 students consisted of 287 current students (including 19 international students) and 177 new students. The outputs of the 287 current students included 55 patent applications, 43 technical reports, 212 journal publications, 2 book publications, and 40 conference papers. As the IAPhD Project aligns with the 5+2 Innovative Industries Plan, we observed innovative regional clusters. By combining regional growth with key national industries, the government aimed to make Taichung the city of Smart Machinery. Universities in central Taiwan have established programs focused on smart machines and manufacturing. In addition, northern Taiwan is known for the semiconductor industry, the Internet of Things, and the biomedical industry. Universities in Hsinchu have established programs focused on semiconductor technology, and those in Taipei have established programs focused on information security and medical engineering.

Finally, feedback from the programs revealed some administrative problems encountered. Influenced by the low birth rate and changing market structure, recruiting students and funding became two significant problems. Although the MOE offers each student an annual scholarship of approximately US$7,000, some of the students indicated that the scholarships are not sufficient to cover tuition and other educational costs. Also, because some programs seek collaborations with small businesses, industry partners cannot meet funding requirements. As part of an attempt to address student recruitment issues and the source imitations of small firms, programs sought ways to increase visibility. Faculty members and students suggested to establish a knowledge network as a platform for the UIC framework to thrive and shine.

Results of alumni survey

In this study, responses were collected from 22 alumni who graduated from 15 programs at 10 universities. Four of the alumni are female and 18 are male. In terms of program type, 12 of the alumni graduated from 5-year combined master's-PhD programs, and 10 graduated from 4-year PhD programs. Additionally, 1 alumnus is an international student who enrolled in 4-year PhD program from 2014 to 2018. Other areas of data collection included alumni experience during PhD studies, employment status, and project feedback.

For alumni experience during PhD studies, we first considered their study period and R&D contributions. In terms of the study period of the 22 alumni, 59% of alumni graduated on time, 14% had late graduation, and 27% graduated early (Figure 4.2.1).

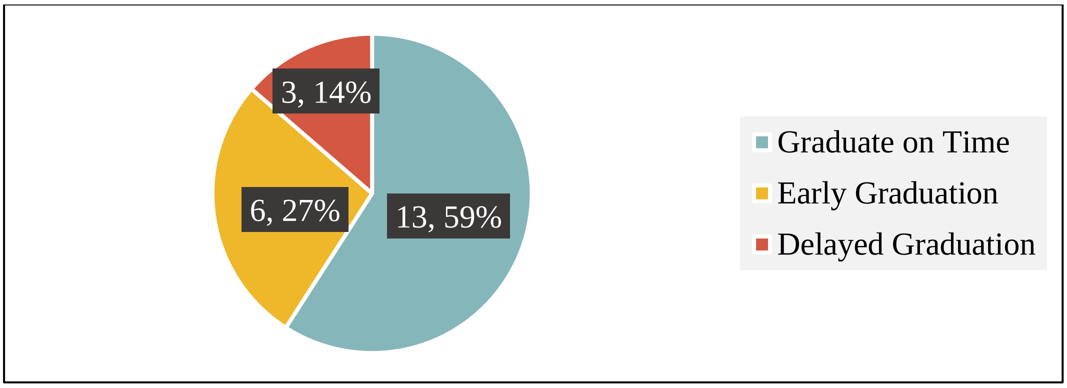


Figure 4.2.1 Study Period of Graduates from IAPhD Project

The average study period of the 5-year combined master's-PhD programs alumni is 4.75 years, and of the 4-year PhD program is 4.10 years (Figure 4.2.2 and Figure 4.2.3).

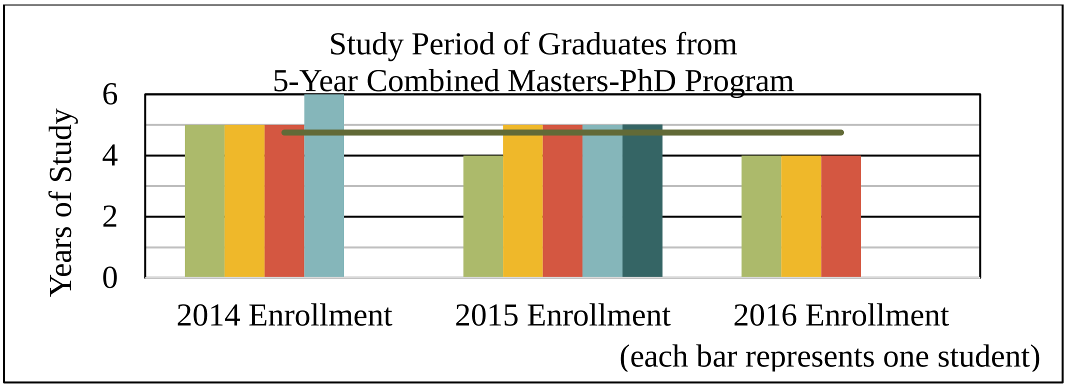


Figure 4.2.2 Study Period of Graduates from 5-Year Combined Master-PhD Programs

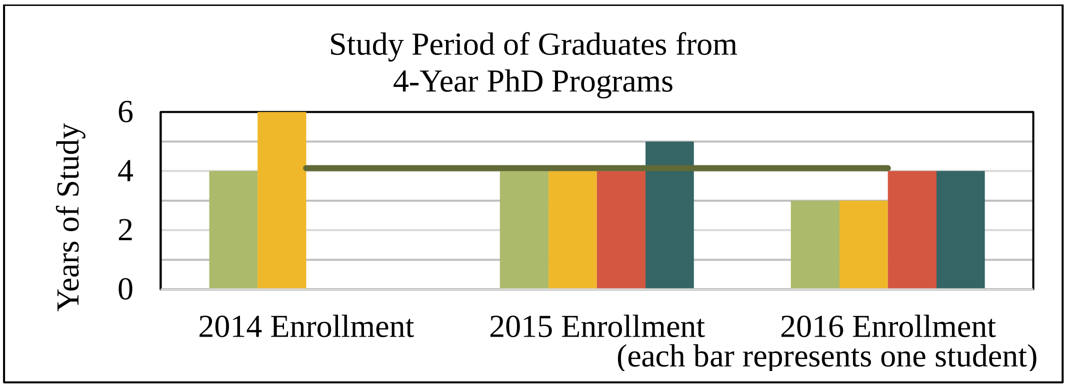
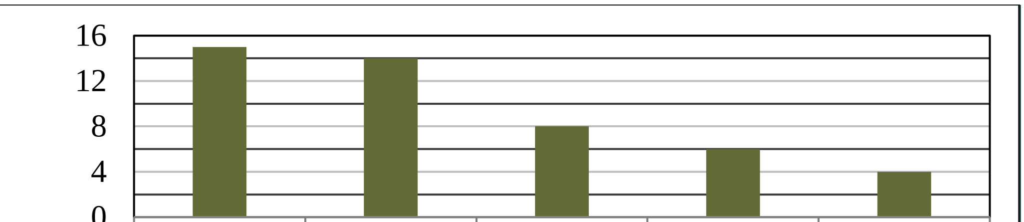


Figure 4.2.3 Study Period of Graduates from 4-Year PhD Programs

For the topics of their dissertations, 68% of alumni's dissertation topics match their internship projects. Key technology and product development were their main R&D contributions (Figure 4.2.4).



	Key Technology	Product Development	Patent Application	R&D Service and Performance	Spin-in or Spin-off
Number	15	14	8	6	4

Figure 4.2.4 Number of R&D Contributions

Second, regarding the employment status of alumni, half of them are currently employed, 23% are now working as postdocs, and 18% are in military service (Figure 4.2.5). Of the working alumni, 6 are still employed by their programs' industry partners. One alumnus is an assistant professor. Among the other alumni, most of the employed alumni are engineers and senior engineers. In terms of the salary level, engineers have an average annual salary of about US$20,000 and senior engineers of about US$30,500.

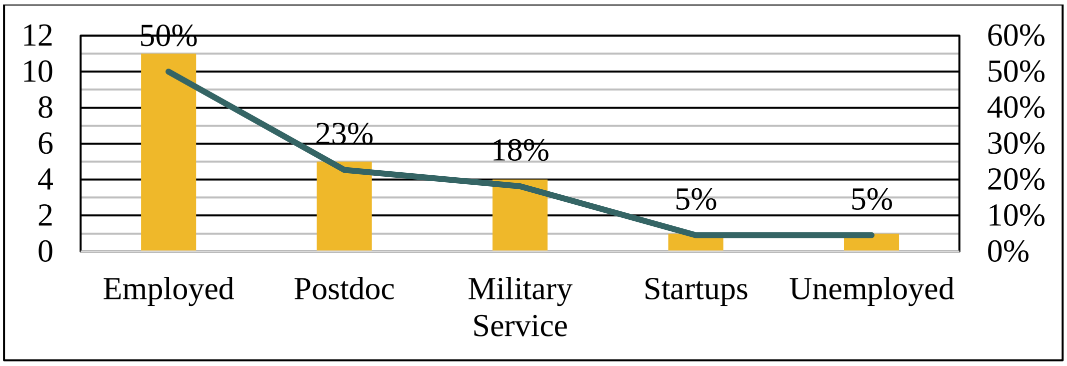


Figure 4.2.5 Employment Status of IAPhD Project Alumni

The final section of the survey focused on project feedback. First, we examined alumni experiences of doctoral study. We found that 77% of alumni agreed that the degree requirements of IAPhD programs should be different from traditional PhD programs. However, one alumnus suggested that while the IAPhD Project emphasized accomplishments, impact factors and journal publications should still be considered essential to PhD education.

In terms of project evaluation, 83% of alumni received adequate training from their industry partners during doctoral study. After the PhD, 95% of them found the IAPhD Project helpful for their career entry. Of the working alumni, 82% found that their current position matched their career expectations (Figure 4.2.6).

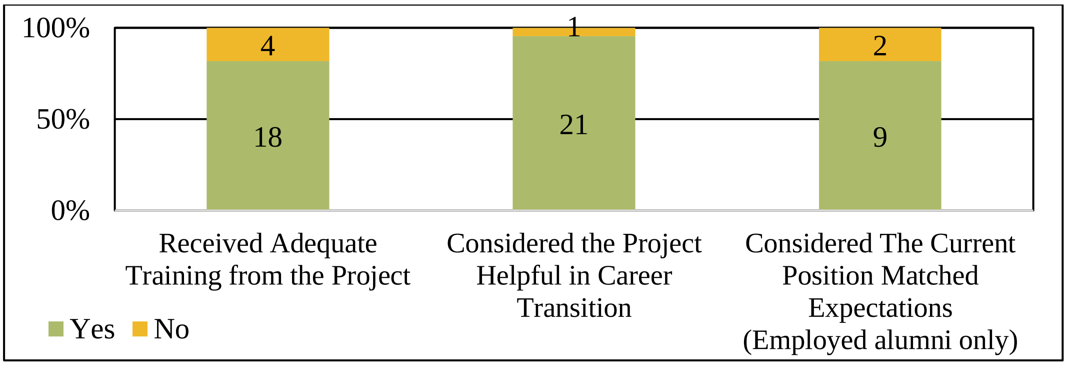


Figure 4.2.6 Project Evaluation for Training for Career Transition

As far as further career planning is concerned, 63% of alumni still plan to enter academia, while 45% consider starting a business (Figure 4.2.7).

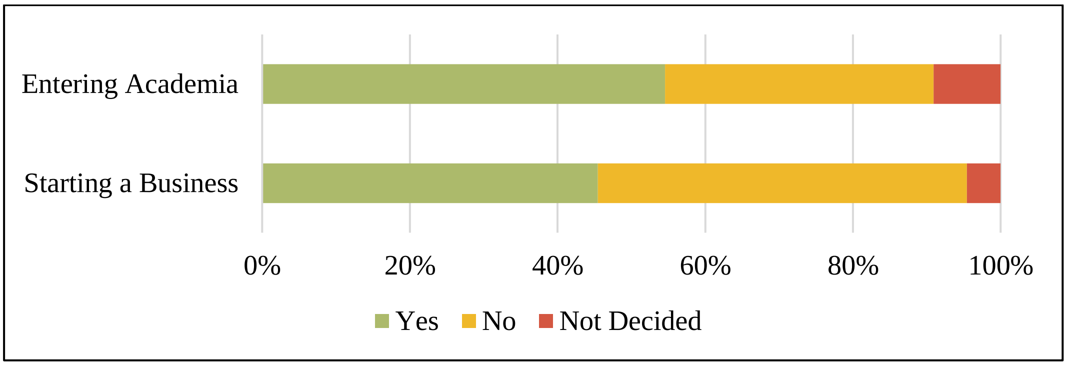


Figure 4.2.7 Future Career Planning of IAPhD Alumni

In reviewing alumni attitudes towards the Project and suggestions for improvement, we received positive feedback. Emphasis was placed on early contact with industry and knowledge of market developments. To improve the Project, alumni suggested expanding the scope in terms of the total number of students participating, industry partners, and scholarship amounts. Some of the alumni pointed out that the scholarships from the MOE could not cover the cost of training and tuition. Since some of the industry partners were small companies, the alumni suggested that international collaborations with larger companies should be encouraged to attract more students and provide other educational experiences. The need to expand the Project led to the alumni's suggestion that the IAPhD Project provided career development support, including hosting workshops on leadership and marketing skills.

High-level talent training among global innovators

To better identify potential areas of improvement for the IAPhD Project, we compared the global innovators mentioned. Since the feedback and suggestions for the Project focus on funding and project promotion, we looked at the number of scholarships for students in each project and the method of evaluation and project promotion.

Preliminary results of the comparison have shown that participating students in the IAPhD Project receive relatively lower stipends than those in the other projects except the WISE program. However, the level of stipends must consider the living standards, salary level, and many other indicators. Meanwhile, students participating in CIFRE and the Danish Industrial PhD Programme receive a salary from their partner industries in addition to the government stipends. Perhaps the Project can consider adjustments in stipends as an incentive for more students to participate.

The IAPhD Project uses the programs' annual reports and alumni surveys as analyses for project evaluation and promotion. Except for CIFRE, which only conducted alumni surveys, all other projects also used the programs' performance reports for evaluation. In terms of project promotion, the IGERT program holds annual video and poster competitions, and the WISE program presents the R&D results of each program. The two projects have shown success in promotion and can be used as references for the design of the Project promotion.

Discussion and conclusion

In the last decade, Taiwan has experienced a drastic decline in doctoral students' enrollment rate due to the low birth rate and changing market structure [3]. At the same time, the gap between industry and academia has led some PhD students to prefer academia over industry in their career choice [8]-[10]. To strengthen high-level talent training and attract more PhD students to the industry, the MOE has been leading the IAPhD Project since 2014 [12]. So far, the Project has approved 79 programs at 29 universities and supported more than 464 students. The current study examined the IAPhD Project's implementation and sought ways to improve the Project and policies.

The IAPhD Project has produced only 22 alumni since its inception. With the small population of current graduates, follow-up with the alumni outcomes is needed to demonstrate the Project's success better. In addition to surveying alumni and analyzing the programs' annual reports, a future study should also investigate industry partners for a more thorough review of project outcomes. In terms of meeting the KPIs, while more than half of the programs met the KPIs, some programs did not. Because some programs did not adjust graduation requirements, the IAPhD Project cannot distinguish its training from traditional programs. Lack of funding was highlighted as an issue in the annual reports and alumni survey. Comparing the IAPhD Project with other global innovators, the total amount of investment in the programs per year is not less than that of the IGERT program [30] and the NRT program of the U.S., the amount of scholarship of the IAPhD Project was less than that of the Danish Industrial PhD Programme [33] and CIFRE [35]. Since the scholarships cannot cover tuition and other training costs, the Project might have a hard time attracting students.

Project highlights were observed in the current study. The participating universities established programs that followed the 5+2 Innovative Industries Plan [37]. In line with the idea that UIC can help to attract talent to the region [25]-[26], we also observed an innovation cluster in the IAPhD programs, namely Smart Machinery industry in central Taiwan, semiconductor industry, Internet of Things, and biomedical industry in northern Taiwan. Participating universities near S&T parks strived for UIC by establishing relevant programs. The IAPhD Project should focus on expanding the Project scope and improving its visibility in the next step. Inviting larger companies to participate in the Project can bring more opportunities for students. By building a knowledge community and holding lectures on topics related to R&D activities, students are expected to gain knowledge on current industry trends, IP policies, career development, and transferable skills. On the other hand, to follow the Project results, this study took the showcases of IGERT [30] and JGRAD [22] as references for the database design of the IAPhD Project.

As high-level talent training in Taiwan is severely affected by declining enrollment [2]-[3], high dropout rates [4]-[5], delayed graduation [6]-[7], and doctoral graduates’ preference to stay in academia [8]-[10], the MOE launched the IAPhD Project in 2014 [12]. The current study examined the employment status of the 22 alumni to understand the outcomes and impact of the Project. Despite the success in alignment between 5+2 innovative industries and participating programs, the Project encountered some problems. Both the amount of scholarships and compliance with KPIs needed to be resolved. To improve the visibility of the Project and expand the scope, the study provided policy recommendations with regards to the UIC model of other global innovators. The analysis provided concrete evidence of the Project’s effectiveness in implementing the training of high-level talent.

References

[1] D. Ziad and S. Johnson, “A $31 trillion question: Turbocharge tech or let productivity plummet?” in *Getting well, Sticking Together, Owning the Future Covid Shock, U.S.-China Rupture, and The World in 2050, Bloomberg L.P.*, November 2020, pp. 51-54, [Online]. Available: https://www.neweconomyforum.com. [Accessed January 25, 2021].

[2] J. Causey, Q. Liu, M. Ryu, D. Shapiro, and Y. Zheng, “A COVID-19 Supplement to Spring 2020 Current Term Enrollment Estimates,” *National Student Clearinghouse Research Center*, June 2020. [Online]. Available: https://nscresearchcenter.org/wp-content/uploads/CTEE_Report_Spring_2020.pdf. [Accessed: January 25, 2021].

[3] Ministry of Education (MOE) Department of Statistics, “大專校院研究生概況 [Summary of graduate students],” *Highlights of Education Statistics*, vol. 114, July 2019. [Online]. Available: https://depart.moe.edu.tw/ed4500/News.aspx?n=B31EC9E6E57BFA50&sms=0D85280A66963793. [Accessed January 24, 2021].

[4] R. Wollast, G. Boudrenghien, N. van der Linden, B. Galand, N. Roland, C. Devos, M. de Clercq, O. Klein, A. Azzi, and M. Frenay, “Who are the doctoral students who drop out? factors associated with the rate of doctoral degree completion in universities,” *International Journal of Higher Education*, vol.7, no.4, pp. 145-156, August 2018.

[5] MOE Department of Statistics, “大專校院學生休、退學概況及就學穩定情形 [Summary of undergraduate and graduate students dropout and retention],” *Highlights of Education Statistics*, vol. 124, May 2020. [Online]. Available: https://depart.moe.edu.tw/ed4500/News.aspx?n=B31EC9E6E57BFA50&sms=0D85280A66963793. [Accessed January 24, 2021].

[6] A. Sundström, G. Widforss, M. Rosqvist, and A. Hallin, “Industrial PhD students and their projects,” *Procedia Computer Science*, vol. 100, pp. 739-746, October 2016.

[7] MOE Department of Statistics, “大專校院學生數概況 [Summary of number of undergraduate and graduate students],” *MOE Department of Statistics*, 2019. [Online]. Available: http://stats.moe.gov.tw/statedu/chart.aspx?pvalue=32. [Accessed January 24, 2021].

[8] L. M. Wood, “Odds are, your doctorate will not prepare you for a profession outside academe,” *The Chronicle of Higher Education*, July 9, 2019. [Online]. Available: https://www.chronicle.com/article/odds-are-your-doctorate-will-not-prepare-you-for-a-profession-outside-academe/. [Accessed January 25, 2021].

[9] Y. -T. Yang, “從學用落差現象談高等教育的價值與未來 [Education-job mismatches and their impacts on the value and future of higher education in Taiwan],” 臺灣教育評論月刊 *[Taiwan Educational Review Monthly]*, vol. 6, no. 4, pp. 32-34, April 2017. [Online]. Available: http://www.ater.org.tw/commentmonth.html. [Accessed January 18, 2021].

[10] R. Lin, “Taiwan’s Stray PhDs,” *CommonWealth Magazine*, vol. 507, October 2012. [Online]. Available: https://english.cw.com.tw/article/article.action?id=639&from=search. [Accessed January 28, 2021].

[11] G. Abramo, C. A. D’Angelo, and F. D. Costa, “University-industry research collaboration: A model to assess university capability,” *Higher Education*, vol. 62, pp. 163-181, 2018.

[12] MOE, “教育部補助大學校院產學合作培育博士級研發人才計畫作業要點 [Industry-Academia Cooperative PhD Project Guidelines],” *MOE*, August 2014. [Online]. Available: https://edu.law.moe.gov.tw/LawContent.aspx?id=GL001342. [Accessed: September 14, 2020].

[13] L. M. Branscomb, F. Kodama, and R. Florida, *Industrializing Knowledge: University-Industry Linkages in Japan and the U.S.*, Cambridge, MA: MIT Press, 1999.
[14] K. Motohashi, "Growing R&D collaboration of Japanese firms and policy implications for reforming the national innovation system," *Asia Pacific Business Review*, vol. 14, iss. 3, pp.339-361, June 23, 2008.
[15] K. Shimuzu, "The Survival of Regional Banks and Small and Medium Enterprises: Maintaining Low Unemployment under Economic Stress," in *Syncretism: The Politics of Economic Restructuring and System Reform in Japan*, K. E. Kushida, K. Shimizu, and J. C. Oi, Eds. Stanford, CA: The Walter H. Shorenstein Asia-Pacific Research Center, 2013, pp. 147-172.
[16] M. Hemmert, H. Okamuro, L. Bstieler, and K. Ruth, "An inquiry into the status and nature of university-industry research collaborations in Japan and Korea," *Hitotsubashi Journal of Economics*, vol. 49, no. 2, pp. 163-180, December 2008.
[17] K. Motohashio, "Economic analysis of university-industry collaborations: The role of new technology based firms in Japanese national innovation reform," in The Research Institute of Economy, Trade and Industry (RIETI) Discussion Paper Series 04-E-001, January 2004.
[18] Ministry of Education, Culture, Sports, Science and Technology Japan (MEXT), "White Paper on Science and Technology 2017 (Provisional translation)", *MEXT*, 2017. [Online]. Available: https://www.mext.go.jp/en/publication/whitepaper/. [Accessed January 27, 2021].
[19] MEXT Japan Society for the Promotion of Science, "Doctoral Program for World-leading Innovative & Smart Education," *MEXT Japan Society for the Promotion of Science*, 2020. [Online]. Available: https://www.jsps.go.jp/j-takuetsu-pro/brochure.html. [Accessed January 27, 2021].
[20] T. Fukuda, "日本版 Industrial PhD 制度(仮称)創設の提言 [Proposal for Industrial PhD Supported by Collaboration between Academic Institutions and Industry]," *MEXT*, 2015. [Online]. Available: https://www.mext.go.jp/b_menu/shingi/chousa/koutou/068/gijiroku/__icsFiles/afieldfile/2015/11/25/1364290_04.pdf. [Accessed January 26, 2021]
[21] MEXT Committee of Japanese industrial PhD, "日本版 Industrial PhD（仮称）制度の創設について～産学官連携によるイノベーティブ人材育成と地方創生～＜中間報告＞[The Establishment of the Japanese version of the Industrial PhD (tentative name): Innovative Human Resources and Regional Development by Industry-academia-government Collaboration (Mid-term Report)]," *MEXT*, 2015. [Online]. Available: http://www.super-daigakuin.jp/pdf/industrialphd.pdf. [Accessed January 25, 2021].
[22] National Institute of Science and Technology Policy (NISTEP), "Japan Graduates Database (JGRAD)," *NISTEP*, 2018. [Online]. Available: https://jgrad.nistep.go.jp. [Accessed January 27, 2021].
[23] National Research Council, *21st Century Innovation Systems for Japan and the U.S.: Lessons from a Decade of Change: Report of a Symposium*, S. Nagaoka, C. W. Wessner, K. Flamm, and M. Kondo Eds. Washington, DC: The National Academies Press, 2009.
[24] B. Carlsson and A.C. Fridh, "Technology transfer in United States universities," *Journal of Evolutionary Economics*, vol 12, nos.1/2, pp.199-232, March 2002.
[25] C. Goldin and L. F. Katz, "The origins of technology-skill complementarity," *The Quarterly Journal of Economics*, vol. 113, no.3, pp. 693-732, August 1998.
[26] C. Goldin and L. F. Katz, "Human capital and social capital: The rise of secondary schooling in America, 1910-1940," *Journal of Interdisciplinary History*, vol.29, no. 4, pp. 683-723, April 1999.

[27] C. -K Wang, “產學合作博士人才培育相關課題與對策之研究 [On Topics and Policies with industry-academia cooperation in doctoral education],” 人力規劃及發展研究報告, vol.18, pp. 25-52, Taipei, Taiwan, April 2018. [Online]. Available: https://www.ndc.gov.tw/Content_List.aspx?n=D5212D9DB8CCF869. [Accessed January 10, 2021].
[28] U.S. Department of Education, “Graduate Assistance in Areas of National Need,” *U.S. Department of Education*, March 2011. [Online]. Available: https://www2.ed.gov/programs/gaann/index.html. [Accessed February 9, 2021].
[29] U.S. Department of Education, “Performance Assessment of 2000 and 2001 Fellows,” *U.S. Department of Education*, September 2006. [Online]. Available: https://www2.ed.gov/programs/gaann/performance.html. [Accessed February 9, 2021].
[30] National Science Foundation (NSF), “Integrative Graduate Education and Research Traineeship (IGERT),” *NSF*, 2018. [Online]. Available: http://www.igert.org/. [Accessed February 9, 2021].
[31] National Science Foundation (NSF), “Evaluation of the National Science Foundation’s Integrative Graduate Education and Research Traineeship Program (IGERT): Follow-up Study of IGERT Graduates,” *NSF*, February 2011. [Online]. Available: http://www.igert.org/documents/481.html. [Accessed February 9, 2021].
[32] J. P. Myklebust, “Industrial PhDs score high on employment and income,” *University World News*, para.3, August 31, 2013 [Online]. Available: https://www.universityworldnews.com. [Accessed January 15, 2021].
[33] Innovation Fund Denmark, “Guidelines for Industrial PhD,” *Innovation Fund Denmark*, October 10, 2019. [Online]. Available: https://innovationsfonden.dk/sites/default/files/2019-10/guidelines-for-industrial-phd-2019-10-10_0.pdf. [Accessed February 8, 2021].
[34] Ministry of Higher Education and Science, Technology and Innovation, “Analysis of the Industrial PhD Programme,” *Danish Agency for Science, Technology and Innovation*, 2011. [Online]. Available: https://ufm.dk/en. [Accessed September 18, 2020].
[35] Association Nationale Recherche Technologie (ANRT), “Cifre,” *ANRT*, 2018. [Online]. Available: http://www.anrt.asso.fr/fr/cifre-7843. [Accessed January 16, 2020].
[36] Association Nationale Recherche Technologie (ANRT), “CIFRE, a passport for employment in a company,” *ANRT*, 2016. [Online]. Available: http://www.anrt.asso.fr/fr. [Accessed January 16, 2021].
[37] Executive Yuan, Taiwan (R.O.C.), “5+2 innovative industries plan,” *Executive Yuan*, May 2016. [Online]. Available: https://english.ey.gov.tw/iip/. [Accessed September 20, 2020].