UNDERSTANDING TAIWAN'S UNIVERSITY-INDUSTRY COLLABORATIONS MODEL: A CASE STUDY OF A PRIVATE UNIVERSITY[1]

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Abstract

Chung Yuan Christian University (CYCU) in Taiwan has established its innovation and incubation centre in 1997, its patent licensing centre in 2003, followed by its Industry-Academia Operation Headquarters in 2009. CYCU ranks as the first in Taiwan's private universities, and its industry-academia cooperation achievements have been increasingly approaching those of National Tsing Hua University (NTHU), one of Taiwan's elite public universities. In 2005, CYCU ranked in the top 100 universities in receiving US patents in the world, and as No. 1 among private universities, and No.4 among all universities in Taiwan. The paper has three major objectives. First, to explain the government's intervention through institutional arrangements and its effect and funding the development of university–industry collaborations in Taiwan in general, and CYCU in particular. Second, to elaborate the Executive Operation Office for Industry-Academia Cooperation (EOOIA) at CYCU as a case study and to explain its achievements. Third, to explore key influential factors from five in-depth case studies in UIG collaborations from EOOIA. The paper provides some implications for the theoretical development of knowledge management, and policy implications for a more effective and advanced level of knowledge transfer in university–industry collaborations.

Keywords: university–industry Collaborations, Knowledge Management, Taiwan, Chung Yuan Christian University

Introduction

Since the 1990s, knowledge economy has become a new mainstream economics topic with technology and innovation as its main drivers. A new phenomenon of the triple helix of university-industry-government (UIG) collaboration has emerged as a new model that employs cutting edge knowledge and technology providing competitive advantages in contributing to national economies (Etzkovitz & Dzisah, 2008; Ranga et al., 2008). In UIG collaborations, the state always play the role as an enabler with policies that encourage knowledge transfer from university to industry, to push innovation, national growth and economic competitiveness. The UIG

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collaborations strategy has been adopted not only by developed nations (Etzkowitz et al., 2000) but also by developing nations like Malaysia (Chin and Lim, 2012; Chin et al. 2018) as a new national strategy to build an innovation ecosystem and establish stronger links between private and public research sectors. However, the ability of states to do so is dependent on the strength of domestic institutions (Weiss, 1998). According to Shapiro and Taylor (1990: 876), "Successful economic development has involved state intervention and improvisation of an industrialisation strategy."

Rybnicek and Königsgruber (2018) had conducted a systemic review of the literature on university-industry collaboration (UIC) to search for what makes UIC succeed. Out of the 103 articles that corresponded to the research criteria of UICs, 56 included quantitative analyses and 47 were qualitative, 26 of which were case studies. "The high number of case studies could be an indication that research regarding UICs is still explorative to a great extent" as Rybnicek and Königsgruber (2018: 227) claimed. The systemic review shows that Singapore and Taiwan are two developed countries in Asia at the forefront of pushing UICs, as indicated by the number of research papers published. However, the system review did not provide a detailed analysis on exactly how UICs work. In Singapore, UIG collaborations are efforts to change the role of universities in Singapore towards an "entrepreneurial university" (Wong, 2006; Wong et al., 2007). On the other hand, from the review of literature, there are quite extensive studies on UICs in Taiwan as compared to Singapore.

The UICs research in Taiwan covered broad themes such as developing a unison framework for managing knowledge for UICs (Hu, Hou and Chien 2019), mechanisms between inputs and UIC outputs and collaboration patterns (Ching 2018), linkages between Taiwan's Industrial Technology Research Institute (ITRI) and universities (Wong, Hu and Shiu 2015), determinants for the performance of the UICs (Hu at el. 2016; Weng and Chang 2016), science and technology policy (Hsu and Wu 2012), impact of government incentive programs on UICs (Yeh and Chen 2012) and UIC incubators (Wang and Hung 2013).

The above studies have provided quite substantial information on UICs in Taiwan. However, all of these studies mainly involve the public universities in Taiwan because research funding from the government mainly favour public universities over private universities. In this context, private universities are marginalized and did not benefit much from the government's incentive programs, such as research grants. Due to the disadvantage and dim prospect of working in private universities, high turnover of academics in private universities is always a challenge to private universities. High performing academics leave to join public universities, especially the few prominent ones, in order to give themselves greater opportunities to secure government research grants and 'brighter' prospects.

In this study, the researchers chose to study UICs in Taiwan because Malaysia and Taiwan, share a common similarity where UICs often invovled small and medium enterprises (SMEs) which are the backbone of the two economies. On the other hand, USM and Chung Yuan Christian University (CYCU) from Taiwan had just signed a MOU for mutual knowledge and technology transfer via faculty and student exchange. For the lead researcher himself, the successful application of a Taiwan Fellowhip has enabled the execution of his research proposal on UICs with two prominent co-researchers at CYCU.

The study is a focus on understanding Taiwan's UIC model involving a private university. Chung Yuan Christian University (CYCU) is selected as a case study because it is the top private university in Taiwan. As a case study, it could help determine the possibilities and limitations of UICs.

The paper has three major objectives. First, to explain the government's intervention through institutional arrangements and its effect and funding the development of UICs in Taiwan, in general, and CYCU in particular. Second, to elaborate the Executive Operation Office for Industry-Academia Cooperation (EOOIA) at CYCU as a case study in terms of its UIC strategies and as well as its achievements. To achieve this objective, the paper aims to understand how the centre of excellence at CYCU integrates with the industry and create a dynamic for the achievements of EOOIA. Furthermore, how does EOOIA builds a long-term or sustainable UIC? Third, to explore key influential factors from five in-depth case studies in UICs from EOOIA. The paper provides some implications for the theoretical development of knowledge management, and policy implication for more effective and advance level of knowledge transfer in UIG collaborations.

The Role of the State

The Taiwan Government plays an important role and has contributed to Taiwan's achievement in science and technology through its swift implementation of public policy, which gives strong support for applied scientific development. Since 1959, the Taiwan Government had formulated its first, long-term and comprehensive set of S&T policies. The Basic Law of Science and Technology (BST) in 1998 (and revision in 2011) provided a sound legal framework for government promotion of S&T progress. The BST has gradually laid a strong foundation for Taiwan's science and technology legal system and further solved the limitation of long-term impediment to the development of Taiwan's technology transfer system. It highly relaxed the regulations of the part-time teachers of the national universities. The BST has an investment impact from both public and private sectors in the UICs and the sharing of research and development (Hsu & Wu, 2012).

Over years, Taiwan's research and development (R&D) expenditure has increased from NT351.79 billion (US$11.39 billion) in year 2008 to NT576.71 billion (US$ 18.66 billion)[2] in year 2017. In terms of R&D expenditure as a percentage of GDP, it increased from 2.68 to 3.30 over the same period (Ministry of Science and Technology, Taiwan). In the World Economic Forum's *Global Competitiveness Report 2016-2017*, Taiwan is ranked No. 12 in company spending on R&D, No. 17 in university-industry collaboration in R&D, and No. 24 in capacity for innovation among the 138 economies surveyed (Executive Yuan, www.ey.gov.tw). For more than a decade, Taiwan has invested 1.7 billion USD every year in UIC activities. However, most capitals continue to originate from public organizations, which account for 80–90 percent of the funds (Huang 2018: 413).

Taiwan's technology-based incubators originates from the government's policy which aims to spearhead the development of a "knowledge-based economy". In 1995, the Small and Medium Enterprise Administration (SMEA) under the auspices of the Ministry of Economic

[2] Conversion rate, 1USD=NT30.9016.

Affairs (MOEA), launched small and medium enterprises (SMEs) Incubation Policy. About three quarter of Taiwan's incubators are operate in universities (Wang et al. 2013: 5).

Chung Yuan Christian University

Chung Yuan Christian University was established in 1955, emphasizing holistic education. It has a student population of around 16,500 with 3,000 Master's and 400 PhD students and has more than 106,000 alumni. For its academic programs, it has eight colleges with 29 departments. It has 38 Masters' programs and 13 Doctorate programs. It has 40 research centres. CYCU has established its innovation and incubation centre in 1997 and then its patent licensing centre in 2003, followed by its Industry-Academia Operation Headquarters in 2009. CYCU ranks as the first in Taiwan's private university, and its industry-academia cooperation achievement has been increasingly catching up with National Tsing Hua University (NTHU), one of Taiwan's elite public universities.

In 2015, CYCU was in the top 100 universities in receiving US patents in the world. In Taiwan, CYCU is the number one among private universities, and number four among all universities in Taiwan for the patents. From 2014-2018, CYCU was ranked by the Center for World University Rankings (CWUR) as Taiwan's top private university and received the highest subsidy from the Ministry of Education. CYCU received the best incubator award in 2002, 2009, 2011~2018, and also the excellent incubator manager award for 2005, 2006, and 2010. It was awarded the Excellent Industry-Academia Cooperation Center award in 2010, 2012, 2014-2018 by the Chinese Institute of Engineers. In the past 19 years, more than 150 companies were incubated by EOOIA. CYCU's contribution to the business sector is consider enormous gained University-Industry Economic Contribution Award (2008-2011) from Ministry of Economic Affairs and also the Excellent Performance of Industry-Academia Cooperation Award (2007-2012) by the Ministry of Education. As of 2017, it has increased its total capital to US$ 65 million for incubated companies. On the other hand, incubatees received 22 SBIR projects, 47 new patents, and 40 technology transfers. Since 2017, CYCU through EOOIA has built up international strategic cooperation partners by setting up seven co-incubation centres in Vietnam & Indonesia, Malaysia, Mongolia, and China.

The Centre for Membrane Technology, Centre for Intelligent Manufacturing (智慧製造合作廠商產業鏈) and Center for Mold & Molding Technology are CYCU's renowned R&D centres. The Centre for Membrane Technology in CYCU is the first of its kind in Taiwan, established in November 2002. Membrane Technology is not just CYCU's leading innovative area, but also leads the university to toward the international research direction. It received the National Industrial Innovation Award in 2011. The Center for Membrane Technology accepts members from the industry and also accepts research projects commissioned by the industry, covering biomedical films, plasma processes, waste solution recovery, electromagnetic protective films, carbon nanotubes, and environmental and energy-saving technologies. On the other hand, the Center for Mold & Molding Technology received the University Contribution to Industry Economic Award for the year 2009 and 2012.

These three centres are the strength and niche areas of CYCU in the Global Research and Industry Alliance (GLORIA). GLORIA is an integration program of the Ministry of Science and Technology that centres on universities' advanced technology fields. It bridges the industry-university-government platforms for linking Taiwan with the global market. It offers industry talents and R&D services. In terms of CYCU's UICs performance, as of July 2019, CYCU had issued 890 patents. It had successfully incubated a total of 192 companies 192 with a few of them listed on Taiwan's Stock Exchange.

Methods

Given the nature of study of UICs, the researchers use case studies as an approach that views any social unit as a whole and not a specific technique of data collection and analysis. It means that the case study attempts "to keep together, as a unit, those characteristics which are relevant to the scientific problem being investigated" (Goode and Hatt, 1952: 331). In case studies employed in this research follow Creswell's (1994: 12) approach where "the researcher explores a single entity or phenomenon ('the case') bounded by time and activity and collects detailed information by using a variety of data collection procedures during a sustained period of time."

Case studies have the analytical power to expand the researchers' "evidence based on the analytical values of UIC information in general and, more specifically, help determine the possibilities and limitations of UICs for assessment of productive linkages between universities and business sector partners" (Tijssen and Wong 2016: 119).

Government Grants and CYCU's Performance in UICs

The Executive Yuan of Taiwan (行政院) proposed an invigorating project to boost the country's economic development. This project has spanned three phases (2007-2009, 2010-2012, and 2013-2015). The first phase, one of policy purposes, is largely motivated by the efforts of improving the UIG collaboration.

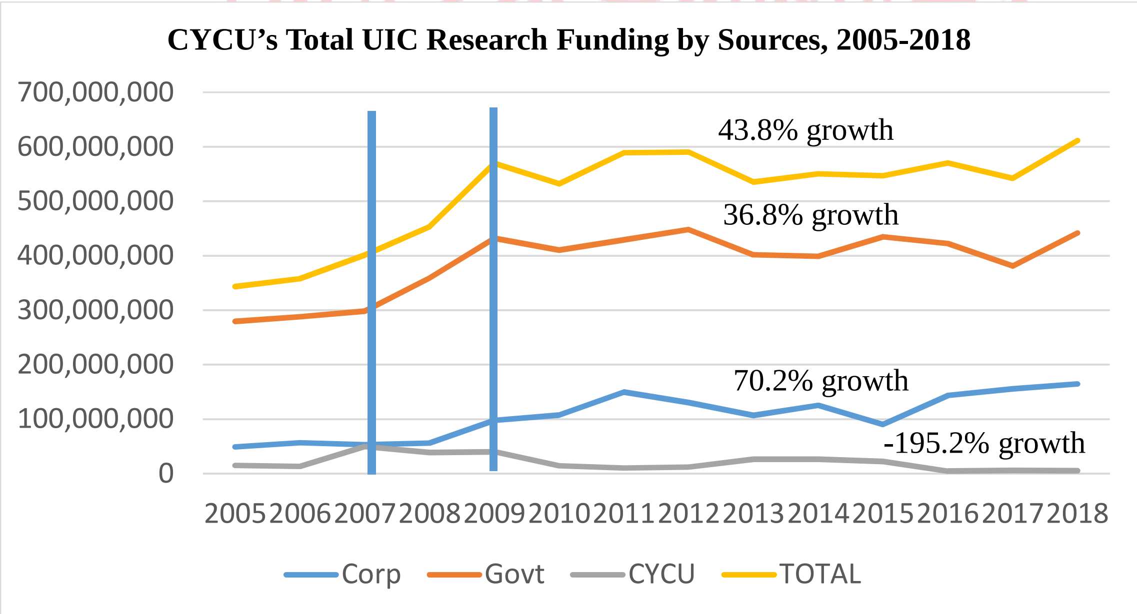


Figure 1 CYCU's Total UIC Research Funding by Sources, 2005-2018

Data in Figure 1 above shows that government's policy to push for UICs had significantly impacted UICs at CYCU, especially phase one (2007-2009). However, research grants for phase two and phase three had become almost stagnant. From 2007-2018, government research grants for UIC grew by 36.8%. Even though in terms of amount, government grants remain substantially higher than research grants from the corporate sector for UICs at CYCU. However, over the same period, research grants from the corporate sector for UICs at CYCU grew at 70.2%, almost double the research grants from the government. It indicates that CYCU's capability in UICs has gained traction from the private sector.

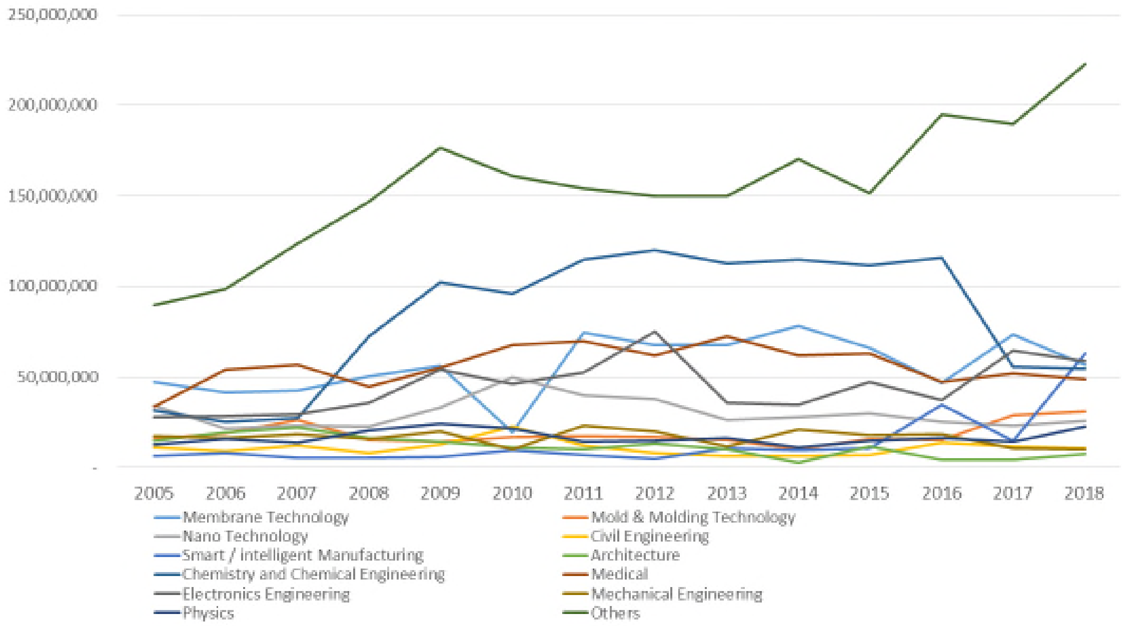


Figure 2. Total UIC Research Funding in CYCU by Expertise, 2005-2018

The overall strength of CYCU's UICs by expertise (2005-2018) is shown in Figure 2 above. Based on the measurement of total research grants from the government and the corporate sector, Chemistry & Chemical Engineering ranks number one followed by Membrane Technology, Medical, Electronics Engineering, Intelligence Manufacturing and Nano Technology. Membrane technology was previously CYCU's top UICs winner, its position has dropped to number two is because of the retirement of its prominent researcher. The prominent researcher also recruited two younger academics from the same department to a public university which promised them better research facilities, research funding and remuneration.

However, when the data is analyzed according to corporate funding (Figure 3), the top five favorites expertise selected for UICs are not rank in order as the total funding. Electronics Engineering ranks first followed by Membrane Technology, Intelligence Manufacturing, Chemistry & Chemical Engineering and Medical. This trend of UICs could be related to the national industry of Taiwan driven by electrical and electronic industry and related manufacturing activities.

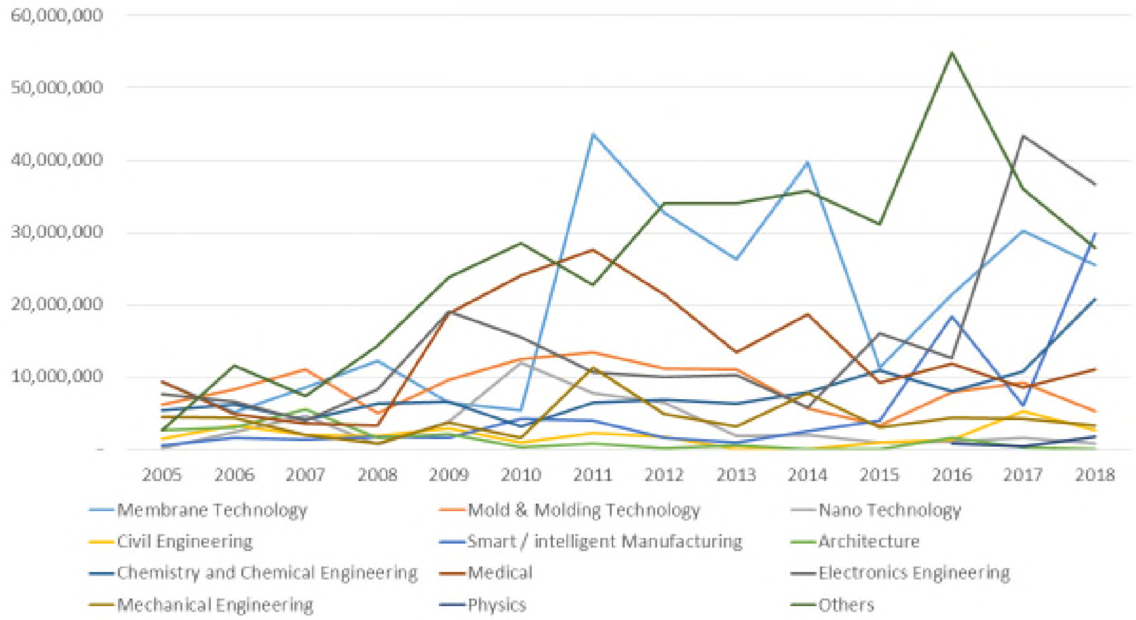


Figure 3. Corporate Funding for UIC Research by Expertise, 2005-2018

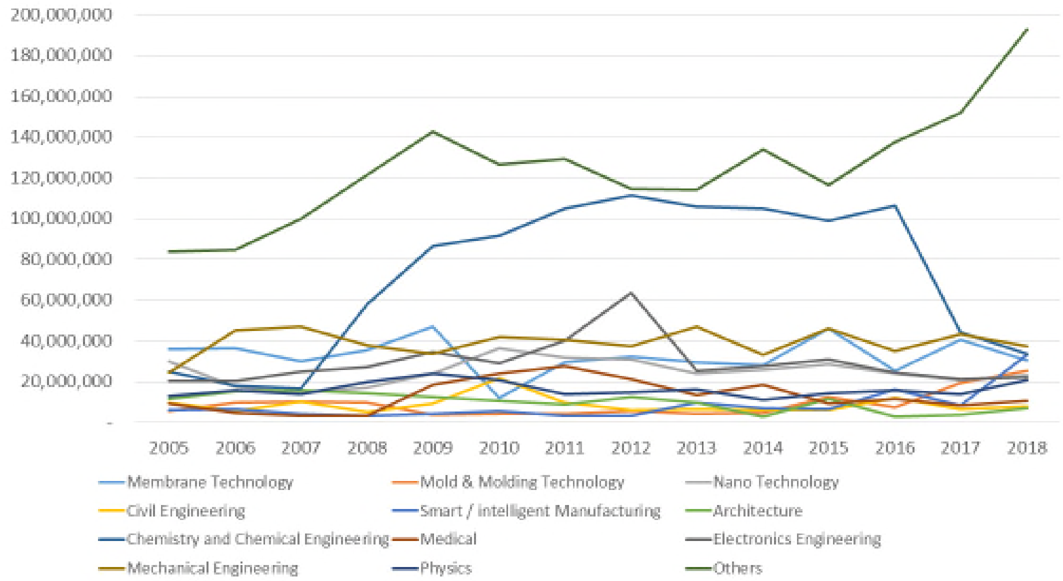


Figure 4. Government Funding for UIC Research by Expertise, 2005-2018

Table 1 Comparison of Sources of Funding for UIC

Top 5 Favorites Corporate Funding	Top 5 Favorites Government Funding
Electronics Engineering Membrane Technology* Intelligence Manufacturing Chemistry & Chemical Engineering Medical	Chemistry & Chemical Engineering Mechanical engineering Membrane Technology Electronics Engineering Nano technology

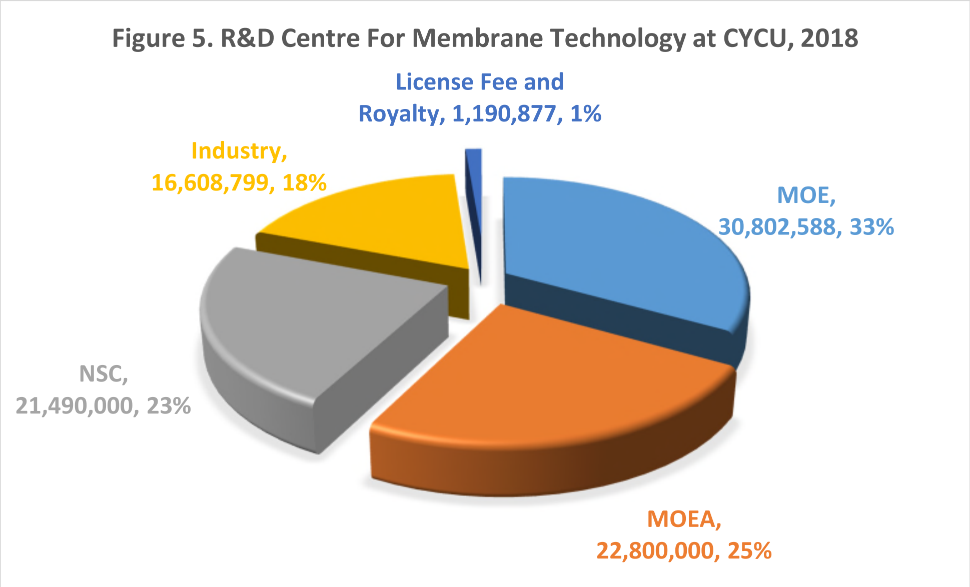
Comparing Figure 3 and 4, we derived ranking of top five corporate and government research grants for UICs at CYCU. As mentioned above, research grants from the corporate sector is closely related to Taiwan's dominant manufacturing sectors in electrical and electronic and related manufacturing activities. On the other hand, the top five favorites government funding for UICs are most probably related to government's emphasis besides the expertise available at CYCU. By expertise, research grants are secured by the credentials of the researcher. If the researcher is famous then it is likely that they will secure more research funding.

Case Studies

The five case studies in this paper enable the researchers and readers to understand the barriers and challenges of knowledge in UICs faced by the stakeholders during its actual implementation. Each of the case study is unique in itself designed by academics and graduate students within the Science and Technology Acts of Taiwan, CYCU's constitutions, willingness of academics and industrial partners, and support from EOOIA as the administrator. The following case studies provide deep understanding of how UICs, the possibilities and challenges to take every case success and to turn CYCU into an entrepreneurial university according to its own unique design as a private university.

Case study 1: Leukocyte Reduction Filter for Red Blood Cells

Leukocyte Reduction Filter for Red Blood Cells is one of EOOIA's most successful cases in university-industry collaboration (UIC). To understand this success, we have to trace back to the foundation of the R&D Centre for Membrane Technology at CYCU laid by its founder, Professor Lai, since year 2000. The founder and head of the centre is a prominent researcher in polymeric membranes who successfully pulled together a group committed and skilled academics in relevant disciplines at CYCU to develop the centre.



Source: R&D Centre for Membrane Technology, Chung Yuan Christian University

The continuous development of the centre is due mainly to its reputation, first established by its founder and with the support of many disciplined and committed researchers. From 2000-2011, with secured research funding from government grants, the centre grew from one laboratory block to four. From 2011-2018, the centre had completed more than 300 research projects with a total research funding of NTD170 million from government sources. Its founder and director who headed the centre until 2016 is Taiwan's top researcher in membrane technology. Due to the founder's reputation and achievements, he had successfully led CYCU to win many major research grants from various government sources such as the Ministry of Economic Affair, Ministry of Education, Ministry of Science and Technology and ITRI. Due to high risks investment, research funding is completely from the government. The centre's other income is from its provision of consultancy, and licensing plus royalty (Figure 5). Over the years, the centre's income was able to develop the centre and enable it to self-sustain, financially. As of 2018, the centre alone contributes approximately 15 percent of the total amount of EOOIA's revenue. The Membrane Centre is the largest research laboratory in CYCU which had produced several top researchers through cutting edge membrane technology. In other words, the centre has a strong foundation with visionary leadership, world-class laboratory and its human capital are instrumental to the success of CYCU's membrane technology development.

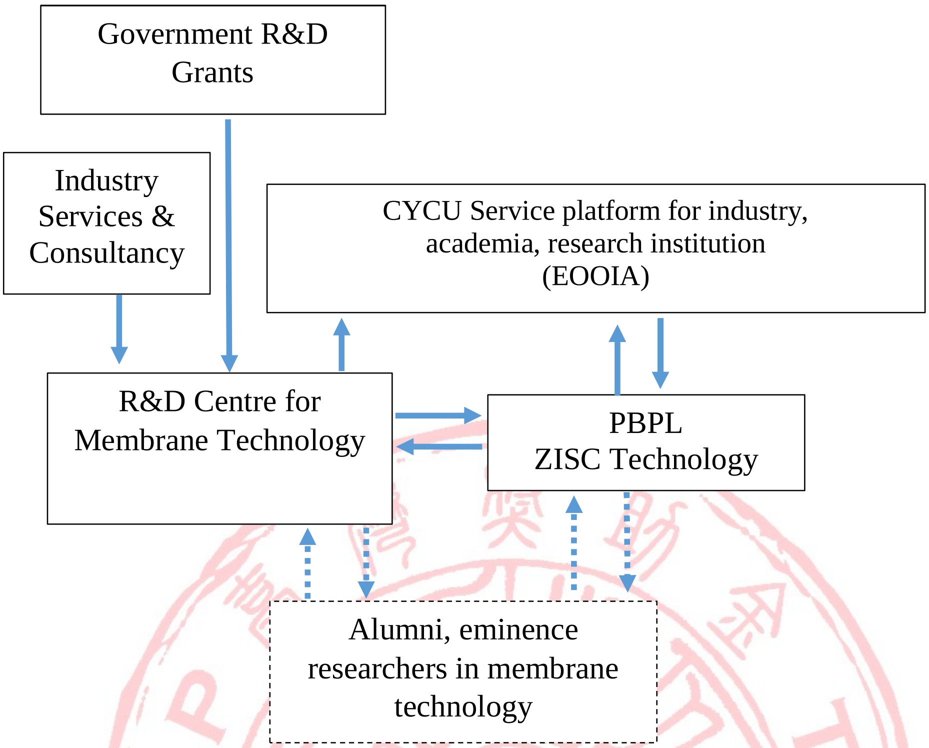


Figure 6. An Ecosystem that Founded the Zwitterionic Interface Ultra-Selfassemble Coating Technology (ZISC Technology)

As of 2016, the centre is headed by its second director, Professor Chang, who was a student (undergraduate) of Professor Chung (in Case Study 2), and Professor Chung was the student of Professor Lai. The centre has a strong foundation that shores up the reputation of CYCU through its state-of-the-art membrane technology research.

In this case study of the development of ZISC Technology (Figure 6), it started in 2006 by Dr. Chang when he was asked by the founder of the Membrane Centre to return and join the centre after his post-doc researcher on medical process in the US. In 2007 Dr. Chang found a niche area on membrane technology in medical field, submitted a research proposal and secured a grant. The research started in 2008 with basic observation, concepts and testing. It faces difficulties when the technology had to go through clinical trials and to get the approval from the Institutional Review Board (IRB) and Protection of Human Subjects in Clinical Trials. CYCU doesn't has a medical school, but a Christian hospital was found as partner for clinical trials. It took about two years to get the IRB's approval.

From a basic research to application and commercialization, this case exposes some issues in UIC. In this case, for setting up a campus company, it involved more than 100 meetings with EOOIA and other parties which the academic felt was unnecessary. The issue of trust emerged and jeopardised the relationship between academic and EOOIA which representing the interest of the university. The academic felt that the many meetings, conditions and legal details set by the university show lack of trust between the academic and the university. On the other hand, the EOOIA takes a different perspective, which is to protect the interests of the university. Commercialization of technology need a different set of skill and language to handle relationship between researchers, university and the industry to make things work out harmoniously. The UIC may become disappointing when both academic and industry do not talk to each other by the same language. This is especially true in areas such as the level of satisfaction after research projects end, the willingness to carry on a technology transfer, and the amount of royalties involved. To overcome the tough negotiation involved different motivations between the two different parties, a standard common language of communication, the Technical Readiness Level (TRL), a popular tool for R&D management, was adopted by the centre to make things clear. The TRL has nine scales that indicate where the academics begin and where the industry starts. An industrial collaboration project would initiate by where both ends meet in the scale (CYCU R&D Centre of Membrane Technology handbook, pp. 50-51).

The ZISC Technology is patented and commercialized through PBPL, a campus company. The technology is used in the production of medical devices. Professor Chang is the single largest shareholder of PBPL and his Master and PhD students each own substantial shares of the company. They raised a total of NTD1,000,000 from bank borrowing as working capital. The transfer of technology licensing to the university involved three types of payments: A total NTD 10 million exclusive licensing fee to be paid by instalments; 15 percent company stocks with non-dilution with company values within NTD100 million; and profits based on revenue. PBPL got its products qualified with Taiwan FDA in 2016 and start its commercialization. PBPL raised capital from angels to acquire US FDA certification for its products because EOOIA's recommendations did not match the requirements and expectations of PBPL. It was a tough beginning with heavy financial commitment. On the side of the academic, with its small size of capital, the licensing fee is relatively very expensive.

In this context of commercializing of technology, CYCU is constrained by the Ministry of Education's policy that prohibits university from venturing into profit making activities and is unable to contribute in monetary form to further participate in the development of campus companies. The issue arising here is that academics feel that all burdens and risks are on them, but not the university. Such a model of cooperation only works if academics are willing.

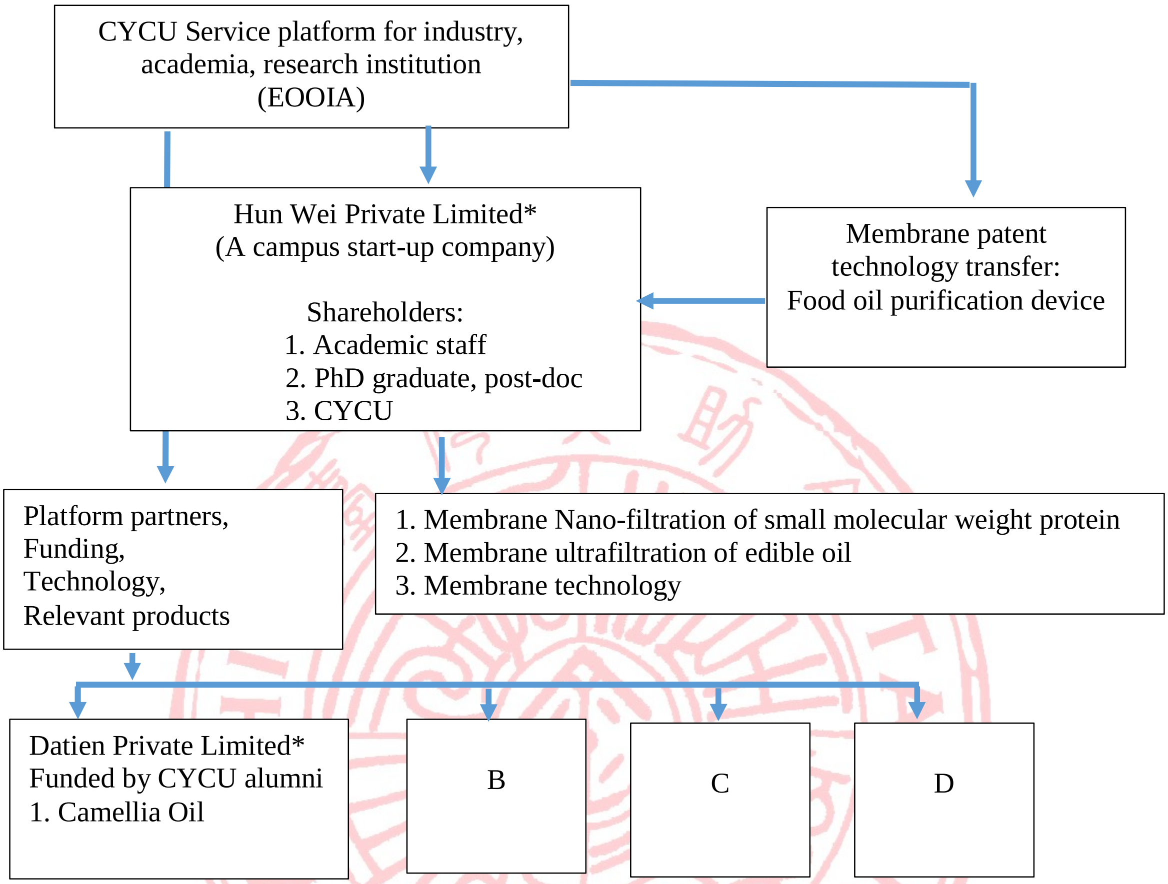
Today, PBPL is managed by Professor Chang's former Master student, and his former PhD student is the Chief Technology Officer of the company, who continues running research at CYCU's membrane centre. Whilst, Professor Chang is advisor of the company. PBPL is providing high quality medical devices that are qualified with FDA, TFDA and other national certifications. PBPL received its FDA approval in late 2018. The company produces the Leukocyte Reduction Filter for Red Blood Cells, which has high leukocyte depletion efficiency for a single unit of red blood cells, outperforming FDA regulatory standards. PBPL is now worth about USD16 million. However, more investment is needed to fund new product development. The journey to greater success has just begun.

This case study reveals several important lessons. First, the change of Science and Technology Policy encourages lecturers to get involved in UIC. Second, a centre of excellence with a strong foundation has the facilities and expertise for producing frontier technology and developing new generations of renowned researchers. Third, the industry and universities lack confidence to invest in high risk frontier research. Fourth, conflicts and issues of trust between university and academics may risk breaking the UIC apart. Conflicts could be overcome by applying the TRL tool which help develop long term collaboration. EOOIA has a role to educate academics who are interested in UIC to understand the TRL1-9 steps, to avoid any potential conflicts. Fifth, UIC involving cutting-edge technology cannot be left alone to graduate students, but academics must fully involve to provide direction and leadership, to achieve significant breakthrough. Moreover, there is a contract to be fulfilled in a UIC. Sixth, top researchers are always the targets of premier national universities, not only from Taiwan but also from abroad. Professor Chang openly made known that ten universities tried to recruit him but he chose to stay on. The manifest reason is his indebtedness to the founder of the centre and to CYCU from where he received help. On the other hand, the latent reason is that CYCU's R&D Centre of Membrane Technology is the most advance in Taiwan, so it is needed for continuous new product development and for new discoveries. PBPL is in a small but important network of relationship and trust with the membrane centre and CYCU alumni who are attached to public premier universities. Relationships with trust help to facilitate collaborative research. Therefore, as long as the membrane centre remains the top centre of excellent, it will be attractive to world-class researchers. Following this, CYCU should play a greater role on the development of the centre. In addition, perhaps CYCU should review its rewarding system for 'super high performers', in order to motivate them to stay on. Besides monetary rewards, new models of technology licensing options and university's participation to shoulder some burden from new ventures should be considered, and choose to trust the academics. The ability to retain high performing staff from leaving the university will lift up CYCU's reputation, followed by increased success rates of research grants applications and attracting more bright students.

Case study 2: Membrane Technology (薄膜技術)

A comprehensive Chemical Industrial Engineering ecosystem started by an academic staff and his PhD student after three years of research. The PhD student continues as post-doc researcher under the same supervision to develop a new device applying membrane technology in food oil purification. Hun Wei Private Limited (HWPL) was incorporated in March 2015 as a campus start-up company which is housed at CYCU's Executive Operation Office for Industry-Academia Cooperation (EOOIA). A non-exclusive membrane patent technology transfer was made to HWPL involved a one-time transfer fee of NTD 4.5 million. The technology involves the separation, purification and concentration on small molecular weight protein from de-oil cake by using membrane filtration.

HWPL is owned by three major shareholders: an academic (the thesis supervisor), former PhD student and CYCU. The former PhD student is a single largest shareholder and Managing Director of HWPL. Under this model of company setup, the supervisor continues his role as an academic at CYCU while the former PhD student is responsible for HWPL's daily operation, he also actively involved as a researcher at the platform with industry partners, improving technology for the development of relevant products such as Camellia Oil.



Note: *Pseudonym.

Figure 7. Academia-university Collaboration on Care Products and Marketing

The product, Camellia Oil is manufactured and marketed under Datien Private Limited (DPL). DPL is co-founded between HWPL and Mr. Khoo who is alumni of CYCU from the College of Engineering. Mr. Khoo is a very successful Taiwanese entrepreneur. He owns a company which has a 30 percent global market shares of charging cables for mobile phones. Since 2015, Mr. Khoo made a pledge to donate NTD10.00 million to CYCU annually. In 2017, Mr. Khoo decided to collaborate with CYCU by tapping into the university's existing expertise in membrane technology to produce high quality Camellia Oil. The purpose of this collaboration is to achieve a sustainable monetary contribution to CYCU in the future. To kick-start this collaboration, Mr. Khoo contributed NTD50.00 million to set up DPL while HWPL contributed NTD6.00 million in kind which include three food oil purification devices, each has estimated market value of NTD2.0 million. In the agreement of collaboration, DPL will donate 12 percent of its annual profits to CYCU. The academia-industry collaboration's value-added service provided by EOOIA includes business model, market research, marketing, design, promotion, international business matching, etc. DPL is presently cooperating with a company to focus on

China, Japan and the ASEAN markets. The product, Camellia Oil, received two international awards. DPL is currently applying for the 22000 Food Safety System Certification to enable the product to be marketed overseas. The Camellia Oil product received the A.A. Taste Award (Hong Kong) and the gold medal Anti Additive award (Italy).

This collaboration model had immediately generated a large amount of money in the form of patent fees for the university. The success of HWPL and DPL is a potential source of revenue for CYCU. They are existing negotiations with company B, C and D to replicate the DPL collaboration model to widen the application of membrane technology. The success of each of this collaboration will increase the monetary reward for all stakeholders. To the university, increased revenue means many things. First, attractive monetary rewards would increase the retention rates of top performing academics from leaving the university. It also will lead to increase winning of researcher grants for CYCU because of the credential of its researchers. On the other hand, CYCU will also attract more graduate students. Second, research and teaching facilities could be up-grated. Third, the well-being of administration staff would be improved, lifting up the morale of CYCU.

This model of collaboration reveals that relationship and return of favour to the university is the major drive of the collaboration, at least for the collaboration with Mr. Khoo and DPL. The generous donation to the university and the large amount of capital injection into the collaboration has a noble purpose, which is to return favour to the university, to benefit the future generations of CYCU's students. A donation of NTD10.00 million from a single donor is not sustainable over a long term. However, the honourable idea to kick start a business joint venture like DPL which has a long-term plan to generate a sustainable large amount of donation for the university will transform the university to scale up its provision of quality education, besides research and development.

Over the last 60 years, CYCU have graduated several hundreds thousand students. It currently has more than 100,000 alumni, of which many have become successful entrepreneurs, and numerous holding positions in top management of large-scale enterprises and conglomerates. It is not just the number of alumni, but also the close relationship and love for the university that will drive the academia-industry collaborations - which is not limited to research and development, and manufacturing, but also sales, marketing, consultation, legal advice etc. In a general sense, with generous support from its alumni worldwide, over the years, CYCU had created an ecosystem in itself.

Case Study 3: The World's Smallest Oscillator

The total research grants received show that electronics engineering has been CYCU's top research area since 2017. One of its major successes is its technology to produce the world's smallest oscillator. Professor Chen, an experienced Analogue Designer, works closely with the semiconductors industry. He is skilled in Application-Specific Integrated Circuits (ASIC) and product development. Professor Chen and his research team comprised of two PhD and seven Master students at CYCU, derived new design and technique to produce the world's smallest oscillator (20 x16 mm^2). They filed three patents, each in the US, Japan and Republic of China. Professor Chen and his former PhD student won the Gold Invention Award for outstanding patent invention for "Oscillation Module and Signals Calibrating Method of the Same" at the 2018 National Invention and Creation Awards by the Ministry of Economic Affairs, Taiwan.

The chip has broad application and markets in wearable devices, consumer electronics, cloud computing, automobile electronics, healthcare and Internet of Things. To commercialize the chip, Professor Chen works with CL Private Limited as details in Figure 8.

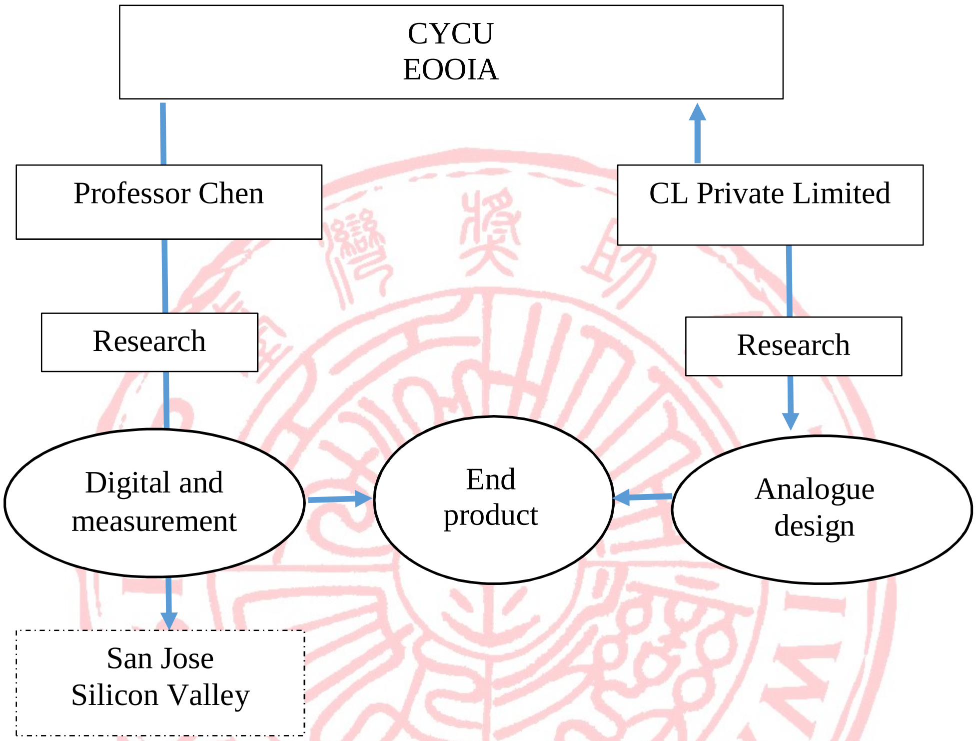


Figure 8. Academia-university Collaboration on Product (Oscillator) Development

This model of collaboration is the choice of the professor which is agreed by the university and the industrial partner. The collaboration started in 2012 with CL Private Limited (CLPL), a local Taiwanese company. CLPL is a non-alumni company. Under this collaboration, they are three forms of financial provision from CLPL to CYCU to support a long-term academia-industry collaboration. First, CLPL pays CYCU the initial patent fees of NTD180,000 per annum. The patent fees will increase according to the profits generated from the sales of chip by CLPL. Second, CLPL finance the R&D works under the supervision of Professor Chen at CYCU. In 2012, the research funding was USD10,000 per annum. As the sales and profits of the product increased, the funding from CLPL for Professor Chen's research team at CYCU in 2019 increased to USD200,000 to support two PhD and seven Master students annually for continuous product (oscillator) development. A PhD student will receive an annual stipend of about USD20,000. The stipend is very attractive which is almost the equivalent to the salary of fresh graduates from engineering. A portion of the fund is spent on the purchase of equipment for research which becomes assets of the university. Third, the Professor gets the equal amount of annual stipend his PhD student is getting. The professor will also receive monetary reward from his publications and reward for his annual excellent achievements. In a separate research on IoT, a PhD student under the supervision of Professor Chen is receiving USD100,000 annually from Taiwan's contract manufacturer. All financial accounts are administered by the university.

The laboratory at CYCU is a platform for training and harvesting of potential talents for the future needs of the industry. Undergraduates involved at the laboratory as research team members for products development are under observation on whether they are good candidates for Master and PhD research programs. Good students will be offered to take up their Master's and PhD research with financial support from the industry. PhD students' research is practically like a full-time job which equips them with knowledge and relevant experience to work in the industry after they have graduated. It is a least cost model to tap on cutting edge knowledge capital at the university to conduct research the industry needed. Engineering graduates which the industry hiring cost about USD50,000 per annum. Professor PhD's students are able to handle 8-inch wafers which cost USD100,000 per piece for their research on oscillators. Engineering graduates that only learned from the book may not have such ability to handle this until they have learned from the industry.

This model of collaboration compels both parties to work hard for continuous improvement on the product. It is interdependent because each party only acquired and owned half of the product technology and knowledge with CYCU controlling the Digital and Measurement technology, and LCPL holding the Analogue Design technology. Therefore, none of them can betray each other. In this collaboration, the CYCU research team has to always be ahead of the LCPL research team for continuous improvement of the chip product.

For further continuous product development, Professor Chen is currently negotiating with a US company at the Silicon Valley in San Jose to set up a research team in the US to support the chip product development at CYCU.

The model shows an existing ecosystem in itself that has a capacity to continually generate new technology and knowledge, and contribute to the industry for new products development. Chips have a very short life cycle in the semiconductor sector and need continuous R&D to always keep ahead of their rivals. From the perspective of global competition, this model has become a part of SME's strategy for competition and survival compare to multinational corporations that can completely develop its own chip.

The model reviews how the industry did not go to other public universities to search for R&D collaboration (in electronics engineering) but to CYCU because they are numerous academics at CYCU who go deep into academia-industry collaboration, especially in products development. Such level of collaboration has its strength and disadvantage. From the perspective of applied research, deep level of academic-industry collaboration which focuses on product development is good for students and the industry. The model has high industrial relevance. For students, research on product development puts students to work on cutting edge knowledge and technology, and allows them experience accumulation, which are relevant to the needs of the industry. The industry will constantly receive new knowledge and innovations, and as well as supply of human capital from the university. A company that has access to knowledge capital in this laboratory with cutting edge knowledge and technology will have a comparative advantage over its rivals.

On the other hand, from the basic research point of view, academics who go deep into product development had chosen a different career path which emphasize on practicality than development of theory in core research areas. Therefore, the 'production' of PhD students under such model of academia-collaboration takes a different orientation with less emphasis on academic contribution but with higher contribution towards the industry.

For a private university like CYCU, the element of sustainability in this model of academia-industry collaboration is important to help generate recurring revenue for the university to fund its administration and R&D development.

Case Study 4: Automation, Laboratories Design, Installation and Testing

The industry seeks expertise from the university through EOOIA and the university's website. For over the past 15 years, Professor Fun from the Department of Mechanical Engineering had helped ten companies, mostly SMEs, to automate their production lines. In all these projects, the industry discussed what they wanted while academics did the design and planning that include software and mechanical engineering to meet the demands of the industry. The President signed all the contracts on behalf of the academics. PhD and Master students learn through executing real industrial projects.

Over the past 15 years, Professor Fun had filed a total of 17 patents. However, he only set up a company, NX Private Limited (NXPL) in 2015 (see Figure 5). The earlier Science and Technology Policy didn't support academic for setting up their own companies. Though he filed for 17 patents from the ten academia-industry collaboration projects, these patents were not commercialized given the nature of the research and demand by the industry is highly specific.

Shareholders of NXPL include Professor Fun with two colleagues and two former students. Under the provision of the MOST policy, the university has a five-percent share in NXPL. Former students are the Chief Executive Officer and Chief Technology Officer of NXPL. The company has not paid any patent fees to CUCY because the patented technologies only used once for each of the company that commissioned the project to the university. The technologies haven't been promoted. NXPL commercializes very limited customized equipment for laboratory use such as for analysing machines that have problems. NXPL also provides laboratory design and installation.

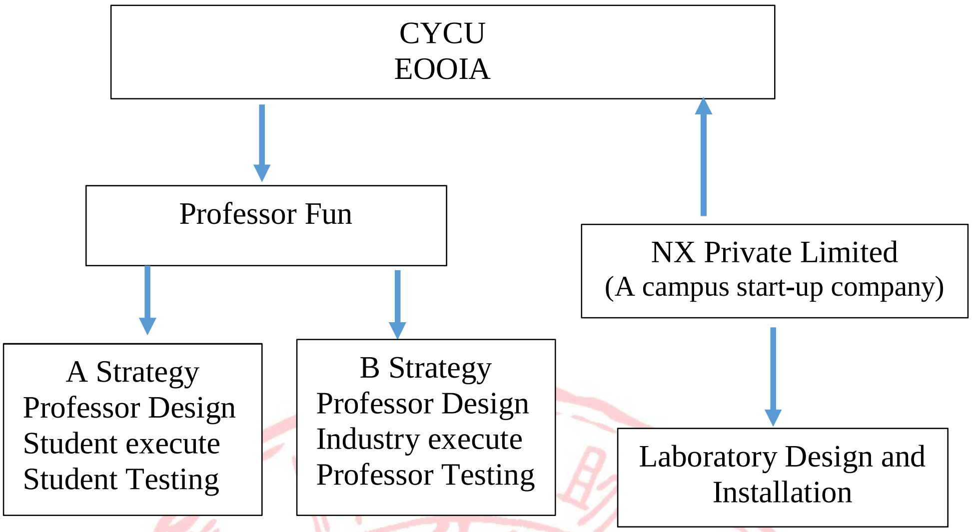


Figure 9: Automation, Laboratories Design, Installation and Testing

In the above model (Figure 9), knowledge transfers to PhD and Master students take place when A Strategy is chosen with the condition that they are sufficient graduate students to work on the secured industrial projects. One of Professor Fun's PhD students who was very interested in research had spent seven years on his thesis and worked on six machines commissioned by different industries. Immediately upon his graduation, the student was given a department head position in a SME. The student chose to work with SME because of the opportunities for him to apply his knowledge.

In the context when they are enough PhD students, Professor Fun would accept more projects from the industry and A Strategy would be executed. Conversely, when there's not enough PhD students, B Strategy would be the option. However, B Strategy involves only the professor and the industry. Therefore, no knowledge is transferred to students. Academics' R&D is also constraint by a limited research fund of NTD 80,000 a year. A Strategy has the element of knowledge transfer to students that is industrial relevant, solving problems the industry is facing. It helps to produce high level of human capital to meet the demand of industry. The only drawback of A Strategy is that it takes longer time, usually one year, to achieve the demand of the industry. In fact, experts in the industry can meet the same demand within three months. The different is the cost which is lower if the solution comes from to the university. Therefore, this model is suitable to meet the demand of industry, usually SMEs who can't afford to pay a higher cost compared to large-scale corporations. They are plenty of opportunities because SME form the backbone of Taiwan's economy.

The transfer of patent licensing and knowledge in the area of mechanical engineering varies compared to membrane technology and electronic engineering. Replication of academia-industry collaboration is narrow for mechanical engineering compared to membrane technology and electronics engineering. Therefore, potential revenue contribution from mechanical engineering is limited. On the other hand, replication of the use of membrane technology is sustainable and broader. Consequently, income generation from membrane technology for the university takes time but could be sustainable over the long-term, compared to electronic engineering. Nonetheless, electronics engineering always need to have the cutting-edge technology because of its short life cycle. Electronic products are widely used globally and rivals are always reinventing new products with the latest technology. The model in the second case study reveals that R&D in a local university-industry collaboration is insufficient to maintain their leadership as the producer of the worlds' smallest oscillator. It has to go beyond local academia-industry collaboration to work with a US company in the silicon-valley, to constantly support its leadership as the world's finest oscillator chip inventor.

Case Study 5: JT Technology (JT) Intelligent Transport Systems

JTT was founded in 2004. It is Taiwan's leading solutions provider for Intelligent Transport Systems (ITS). It provides ITS services to Taiwan's public transports system. The company offers products such as Advanced Driving Assistances Systems (ADAS) with precise position mechanism for Buses & Trucks, Intelligent E-Bus-Stops & management, Barrier Free Bus-Waiting system & management and etc.

JTT has an incubator at EOOIA since 2010. From a discussion with the supervisor responsible for the northern reason of Taiwan, availability of expertise at CUCY such as electronic and civil engineering is the main reason of the company's choice as collaborator to improve its services. The company also has collaboration with Feng Chia University in Taichung City and National Cheng Kung University in Tainan City for different needs to improve its services and develop new products.

This model has a two-way knowledge transfer where the company provides data (BIG data) to academics, not just in CYCU but also to two other universities in Taiwan for continuous service upgrade and spinning new research areas and new businesses. WMPL has an incubator at CYCU which provides internship for undergraduate students.

Conclusions

Compared to MIT, CYCU's model and direction of research, income generation and continuous donations from increasing pool of alumni who are successful entrepreneurs or businessmen and employee of top management in large and high performing enterprises will continue to be a driving force for increasing cases of UICs and spinning off more researchers and with new innovations and invention of new products and improved services to Taiwan's industries. As a private and non-profit university, highly successful UICs will boost the university's revenue and followed by other positive chain effects. A few high profile UICs had just begin to gain momentum: if their entrepreneurial dream is able to hit the global market then CYCU would be heading toward an entrepreneurial university according to its own uniqueness.

They are multiple models of UICs within CYCU, and flexibility, trust and relationships are keys to ensure more success cases. University policy with flexibility on UICs will provide academics more freedom to develop their research capacity. University support and rewards with fewer interventions in UICs, is one way to increase the retaining rates of high performance academic staff. Therefore, sustainability of UICs is the greatest challenge for CYCU.

CYCU has reputable COEs, such as the R&D Membrane Technology. Resources should be allocated to further develop its potential. At the same time, it is necessary to identify the potential of other COEs at CYCU and develop them.

CYCU's deep engagement in UICs has its strengths and weaknesses. The strengths are CYCU's ability of closing the knowledge gap between the university and industry. The various models of UICs somewhat provide students, mostly graduate students with cutting-edge knowledge to take on R&D work in the industry, upon their graduation. On the other hand, academics are also working closely with the industry for continuous improvement of products development. The relative weakness of a deep UIC may skew students' learning towards problem solving rather than theoretical knowledge development. However, it is up to the university which direction it is taking, to find its niche for the enhancement of a better society and contribution to developing a competitive national economy.

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