

Practice School: A STEM Model for Higher Education in Thailand

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ABSTRACT

As an emerging economy, Thailand needs educational reforms to drive the country into a more knowledge-based society to ensure its long-term sustainability. King Mongkut's University of Technology Thonburi (KMUTT), located in Bangkok, has a long history of excellence in science and technology, and is a pioneer in adopting new learning paradigms. The STEM (Science, Technology, Engineering, and Mathematics) educational model has been implemented at KMUTT in the form of the practice school model, starting with Chemical Engineering in 1997 in a new curriculum called Chemical Engineering Practice School (ChEPS). ChEPS is a two-year international Master's degree curriculum, which requires that all its students go through one semester of compulsory full-time work-integrating learning (WIL) in the second year. The practice school is structured in such a way that students learn better and faster at placement companies because of the real-life nature of projects, the industry's commitments, and the presence of full-time KMUTT staff who work closely with the students. Companies benefit tremendously from the output generated by interned students.

Following the success story of ChEPS, KMUTT expanded the practice school model to a number of other graduate curricula, namely food engineering, tapioca starch industry, bioinformatics and systems biology, biotechnology, and biopharmaceutical engineering. While each curriculum has its own operational challenges, students in each program are able to develop active and self-learning as well as soft skills such as English proficiency, team building, and communications. More recently, KMUTT established the WIL Office to promote and support work-integrated learning at the undergraduate level. The aim is to integrate the practice model into a large percentage of curricula across different schools and faculties. Undergraduate WIL is also interdisciplinary in nature, being able to draw students from different departments, e.g. chemistry, physics, biology, mathematics, instrumentation, engineering, etc., to work closely on projects at placements. So far, this teaching and learning paradigm has proven very successful and beneficial to all three stakeholders, namely the university, the industry, and the student. Finally, the win-win-win practice model is gaining a lot of traction and is being emulated at several other universities in Thailand.

1. Introduction

In the late 1990s, educators in the US coined the term STEM which stands for Science, Technology, Engineering, and Mathematics. The acronym is often used when educators address education policy and curriculum development aimed at increasing a country's competitiveness in science and technology. In the US, STEM education has received a lot of attention because of its potential in addressing the perceived lack of qualified candidates for high-tech jobs by effecting positive changes in education policies, curriculum revisions, and workforce development [1]. In addition, STEM education brings about integrated curricula by combining technical aspects from the fields of science, engineering, mathematics, and information technology. Thus, graduates from STEM education should possess qualifications suitable and ready to serve the high-tech industry.

The STEM model is very relevant in Thailand. While Thailand may not suffer from an acute shortage of new graduates in science and engineering, few of these graduates possess the necessary analytical skills to succeed as researchers and engineers. One reason is that most science and engineering curricula in Thailand still rely on the traditional methods of learning, such as classroom lectures, homework assignments, and laboratory work, which are tightly structured and teacher-directed [2]. Although this training is effective to a certain extent, there exists a gap in the skills students possess, particularly the so-called soft skills. Moreover, rote learning and "spoon-feeding" are prevalent in classroom, even at the college level, and there is little emphasis on critical thinking. Finally, most technical curricula are taught in isolation and multidisciplinary fields are scarce. As a consequence, students often lack the experience to apply the theories they learned in classroom to solving real-life problems when they step out into the real world.

Soft skills can be defined as personal attributes needed for a professional to work effectively and efficiently. For example, English proficiency is considered an important soft skill for Thai graduates in the technical fields. In today's global economy, with the advent of ASEAN Economic Community (AEC) in 2015, and with a substantial foreign direct investment in billions of dollars annually in Thailand, the importance of English cannot be overemphasized. Unfortunately, English takes a backseat in most science and engineering curricula. Students have very limited exposure to English, and there is little incentive for them to improve. In addition, Thai companies often complain about the inadequate training of university graduates in communication, another crucial soft skill. These facts are hardly surprising, given that most curricula are taught in Thai with insufficient emphasis on technical writing and oral presentations. Other important soft skills relevant to STEM include human relations, team building, negotiating, and conflict management. As a result, to compensate for the deficiencies in the educational system, companies are often forced to invest substantial resources on re-education and on-the-job training for starting scientists and engineers.

2. Practice School Model for Work Integrated Learning

Work-Integrated Learning (WIL) can be defined as a learning process that occurs through placement. A WIL program integrates internship which, besides teaching core subjects, provides students with an opportunity to practice and be trained under an industrial setting [3]. WIL

pedagogy is known to promote self-learning and soft skill development in students. WIL comes in many forms due to its adaption to different disciplines, and is also known as co-operative (co-op) education, experiential education, practical training, internship, professional training, just to name a few. Regardless of its name, for it to be effective, a WIL program should allow students to work full time in a placement for at least one semester and is required to clearly specify expected learning outcomes and learning assessment methods. Moreover, concrete steps must be taken to prepare students for placement.

King Mongkut's University of Technology Thonburi (KMUTT) is an autonomous state institution in Bangkok with a long tradition in science and engineering. As early as 1996, the university recognized the many shortcomings described above in its curricula. Shortly after, KMUTT introduced a practice-school WIL model at the graduate level aimed at overcoming these deficiencies. This initiative was to develop a new pilot engineering curriculum with the objective of producing well-rounded engineers who possess strong technical competency, can communicate effectively, and have good English proficiency. If proven successful, the goal was to expand the initiative to include other science and engineering fields. All of the practice-based curricula must meet the following common criteria:

- ❑ *International.* Lectures and presentations must be conducted in English. Reports and homework assignments are written in English as well.
- ❑ *Graduate program,* so that it is small enough and can be efficiently managed.
- ❑ *Practice-based,* i.e. the curriculum includes compulsory industrial or laboratory internship.
- ❑ *Strong linkage to the private sector,* which offers industrial sites needed for practical training.
- ❑ *Adequate funding* to attract top-notch students.

Figure 1 illustrates the four essential components in the practice school, namely the university, the funding agency, the student, and the industry.

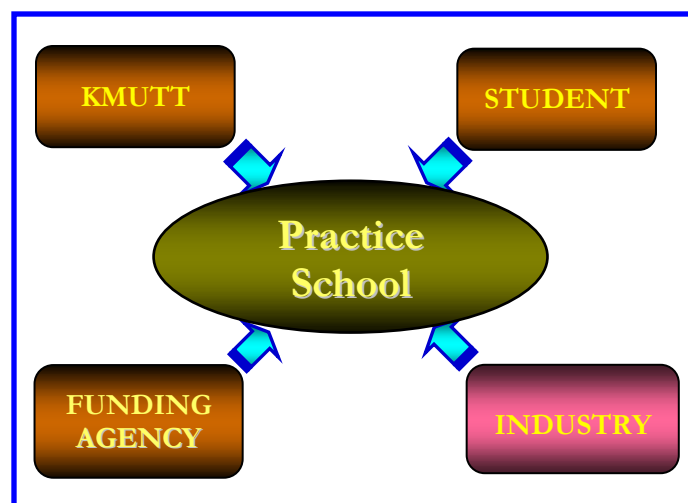


Figure 1. The Four Essential Components of a Practice School

The funding agencies are state, semi-private, and private organizations, which provide research grants and scholarships to academic programs. All practice schools at KMUTT relied heavily on such agencies for financial support in their operations during the early years. In subsequent years, the source of funding gradually shifted to the industry. In a traditional graduate program, the industrial component is normally missing or its role is limited. On the other hand, industrial involvement is vital to the success of a practice school to ensure that students are trained to solve real-life problems early in their studies. These industry-relevant problems are identified by industrial sponsors, and are either brought to the classroom as case studies (problem-based learning or PBL) or solved as site projects during internships.

KMUTT chose Chemical Engineering in the Faculty of Engineering to be the pilot program and founded the Chemical Engineering Practice School (ChEPS) in 1997 [4]. Once proven successful, this pilot program would in subsequent years be succeeded by similar programs in other science and engineering disciplines. Finally, another objective was to expand the practice school model to include undergraduate curricula as well. KMUTT's ultimate goal was to be able to run a large percentage of its academic programs and curricula under the practice school model so as to make a significant impact on improving the overall quality of teaching and learning within the university.

3. Chemical Engineering Practice School (ChEPS)

The ChEPS program was the first practice school to be established at KMUTT. Its curriculum was modeled after the David H. Koch School of Chemical Engineering Practice at Massachusetts Institute of Technology (MIT) in the US, which offered all the desired components in its curriculum [5]. The Practice School at MIT was established in 1916 with the goal of supplementing classroom studies with practical training in an industrial environment. The program is truly unique in the US and is found only at MIT. Enrolled students are required to do two academic semesters of coursework, followed by an additional term of industrial internship. This internship replaces the research thesis found in a conventional Master's degree program. Graduates of the MIT's Practice School are some of the most sought-after engineers in the country. MIT was retained as an advisor, and professors from its practice school traveled to Thailand to help set up the program, assess its readiness, and teach selected courses. The first class of ChEPS consisted of 21 students, all with B.S. degrees in chemical engineering, who were recruited from universities all over Thailand. In subsequent years, 15 – 30 students were admitted annually.

The ChEPS curriculum consists of one academic year (two semesters and one summer) of coursework, one semester of internship at a practice site, and one semester of research, as illustrated in Figure 2. The coursework is fixed and there are no course electives. One objective when starting ChEPS was to introduce Western-styled learning into Thai classrooms. The ChEPS curriculum emphasizes both problem-solving and intensity. The whole program can be viewed as a *learning boot camp*, where PBL is emphasized and students are constantly challenged to solve problems in real plants, sometimes with limited data and many constraints.

Course lecturers consist of both local and overseas instructors, including professors from the US, Canada, Australia, and Singapore. First-year courses comprise core intermediate and advanced chemical engineering subjects.

In ChEPS, computers and software packages are heavily used to supplement classroom lectures. Many courses offer hands-on workshops that demonstrate applications of the theories taught. As a result, ChEPS students are well-versed in many simulation programs and programming tools such as ASPEN PLUS™, PRO/II™, MATLAB™, LINDO™, ControlStation™, and CFX™.

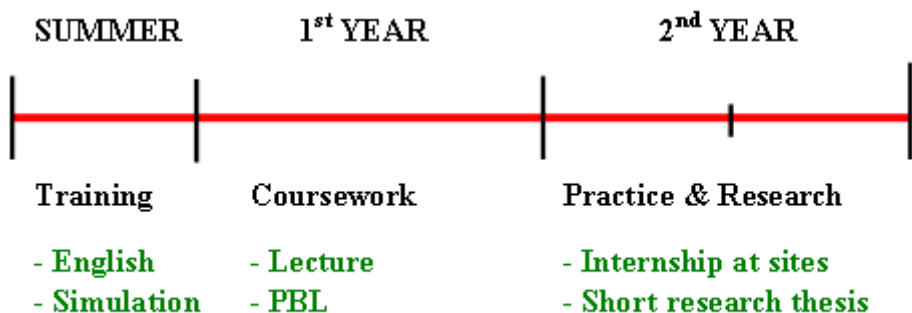


Figure 2. Timeline of ChEPS Curriculum

3.1 ChEPS Placements

Industrial involvements are vital to the success of ChEPS. Sponsoring companies allow ChEPS faculty and students to access their production facilities, also known as practice stations or placements, which play a pivotal role in providing practical training for students in the second year of their study. At the same time, sponsoring companies gain valuable human resources who can work on longer-term projects, thus freeing up company engineers to focus on more urgent needs. Consequently, maintaining this win-win partnership model between the university and the private sector hinges on the successful operation and implementation of practice stations.

The duration of the practice phase is five months. Students work in teams of two or three on two projects in series, and take turns being the project leader. So each project is 10 weeks long, during which there is a proposal presentation, a progress presentation, and a final presentation. ChEPS faculty on campus also travel to the site and attend these presentations to provide further input. Due to time constraints, most site projects tend to be simulation-oriented, which seek to debottleneck, troubleshoot, and optimize (e.g. minimizing energy consumption) existing plants. A few projects also involve feasibility studies and design of new processes. The practice team can be likened to a consulting team who are dedicated to solving problems for the host company. Ku *et al.* (2007) discussed the operation of a chemical engineering practice station in detail [6].

It should be stressed that the industrial internship in a practice school is not a cooperative education program (also known as co-op). The practice model and the co-op study are different in two important aspects. One is the presence of a full-time ChEPS faculty member, called a site director, who is dedicated to a practice station. The site director lives and works with student interns in housing provided by the sponsoring company. While company engineers identify and

set the scope of the projects, the site director is responsible for ensuring the academic value of the proposed work, that the project goals are attainable, and that the work is carried out as planned. Furthermore, the site director provides technical advice, prepares students for presentations, and edits students' reports.

The second difference is the commitment of the host company at every level to the practice school, beginning with basic needs such as free housing accommodations, office space, computing facilities, and Internet access. Senior management is first approached, which sets a top-down policy on sponsoring ChEPS. Plant managers, engineers, shift operators, and technicians are also consulted, since they have to interact with the students. A team of engineers is then formed to work closely with students. In a nutshell, the practice school is more structured, and is therefore far more effective than the traditional co-op study.

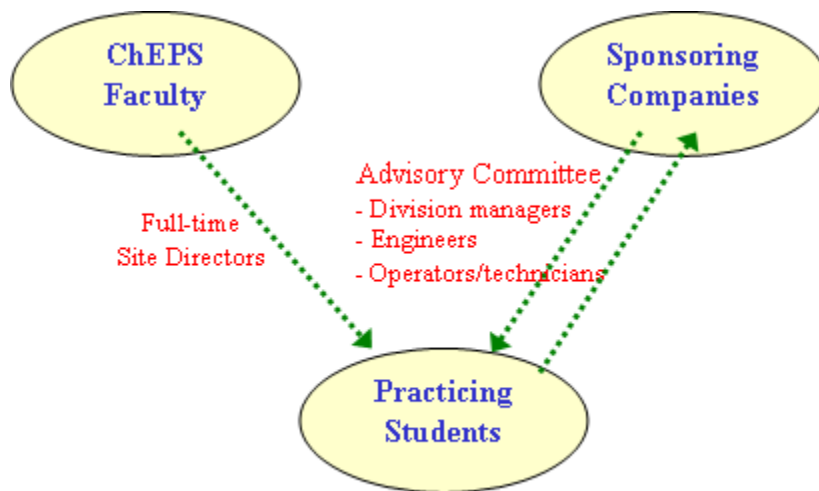


Figure 3. Working Relations in a Practice School

Table 1 shows a list of past and present practice stations in the ChEPS program. Except for ThaiOil and ExxonMobil which are located in the Sri-racha Province (about 150 kilometers southeast of Bangkok), the remaining companies are all located in the Mathaphut Industrial Estate in the Rayong Province (about 180 kilometers southeast of Bangkok).

Company Served as a Practice Station	Service Period
Aromatics (Thailand) Public Co., Ltd.	2002 – 2005, 2007
BST Elastomers Co., Ltd.	2001 – 2002
ExxonMobil Limited	2007
PTT Chemical Public Co., Ltd.	2008 – Present
Rayong Olefins Co., Ltd.	2002 – Present
Thai Oil Public Co., Ltd.	1999 – Present

Thai Polyethylene Co., Ltd.	1998 – 1999, 2001, 2007 – Present
Siam Mitsui PTA Co., Ltd.	2003, 2007 – Present

Table 1. Past and Present Practice Stations of ChEPS

3.2 Program Output and Evaluation

Despite the similarities, the ChEPS curriculum is not an exact duplicate of the MIT model. Certain components were added to ChEPS to enhance the MIT model and compensate for common weaknesses in Thai students. For example, ChEPS introduced a course in engineering management to enable students to better manage time, people, and projects and gain a rudimentary understanding of corporate finance. Moreover, the program is lengthened to two academic years and one summer to accommodate the intense workload and schedule of the students. Additionally, ChEPS is supplemented with the following components:

- ❑ *Presentations.* Students hone their presentation skills by giving no fewer than 30 talks by the time they graduate. Presentations are required in every phase of ChEPS, including PBL problems, research thesis, and site projects.
- ❑ *A short research thesis.* Every student must pick a thesis project to be completed in six months. The extensive networking of ChEPS inside and outside KMUTT, including overseas institutions, allows a student to choose just about any chemical engineering related topic that is of interest to her. In many cases, research projects are collaborated, which offers an opportunity for students to carry out part of their research outside Thailand, e.g. in Canada, the US, Singapore, and Abu Dhabi. Although ChEPS is a practice-based curriculum, many students find the thesis training useful. The students learn to think critically and analytically and must devise a systematic approach to solve a research problem. In fact, many ChEPS graduates have gone on to pursue Ph.D. degrees at other institutions, both in Thailand and overseas.
- ❑ *English tuition.* ChEPS requires that all students score at least 500 on the paper-based TOEFL (called PBT) or 650 on TOEIC by the end of their second year. This is a daunting task for most students. Hence, extra English courses are provided and students' progress is monitored closely. Students are required take either the TOEFL or TOEIC at least once a year. More recently, a mentoring system has been set up in which faculty members are responsible for a small group of students, helping them improve their writing, presentations, and English in general.

ChEPS is highly competitive and admits approximately 25 top-quality students from a pool of slightly more than 100 applicants from various universities in Thailand each year. For example, about two-thirds of ChEPS applicants have an undergraduate GPA of 3.0 or above in chemical engineering. As a result, the program has an elaborate admission process to ensure that only the best are admitted. A number of criteria including undergraduate GPAs, TOEFL English test, SAT Math test, and interview scores are used to screen the applicants. Each admission criterion

is given a weighting factor, with GPA having the highest impact. Viravaidya *et al.* (2007) presented findings on the relative significance of admission criteria in the ChEPS program [7].

The success of ChEPS can be judged on many levels. One is the academic records of the admitted students. Table 2 shows the distribution of universities and the average GPA of admitted students from Class 1 to Class 19 (Academic Year 2015). The table shows that ChEPS students are well represented by every university in Thailand that has a chemical engineering department, and that the caliber of the students applying to and admitted into ChEPS has been exceptional. Academically, admitted students are typically ranked in the top 20% of their respective classes with an average GPA of 3.27.

University	No. of Students	Avg. GPA
Burapha University	6	3.12
Chiangmai University	14	3.42
Chulalongkorn University (Chemical Technology)	16	3.19
Chulalongkorn University (Chemical Engineering)	32	3.12
Kasetsart University	46	3.15
King Mongkut's Institute of Technology Ladkrabang	48	3.24
King Mongkut's University of Technology North Bangkok	26	3.27
King Mongkut's University of Technology Thonburi	159	3.34
Khon Kaen University	2	3.33
Mahidol University	20	3.31
Prince of Songkla University	4	3.37
Silpakorn University	3	3.04
Srinakharinwirot University	1	3.45
Suranaree University of Technology	1	3.09
Thammasart University (ChE & SIIT)	27	3.21
University of Waterloo	1	Excellent Stand.
Total	406	3.27

Table 2. Academic Profile of Admitted ChEPS Students, Class 1 – 19

Another indicator that can be used to gauge the success of the ChEPS program is the track record of employment of its alumni. Figure 4 shows the employment profile, categorized by industrial sectors, of ChEPS alumni based on 365 students from 17 classes. About half of the graduates currently work for large chemical, petrochemical, and refinery companies. A sizable number also work for small-to-medium enterprises (SMEs), e.g. those in the sugar and food industries.

Finally, about 12% of ChEPS alumni have become affiliated with universities or went on to pursue PhD degrees.

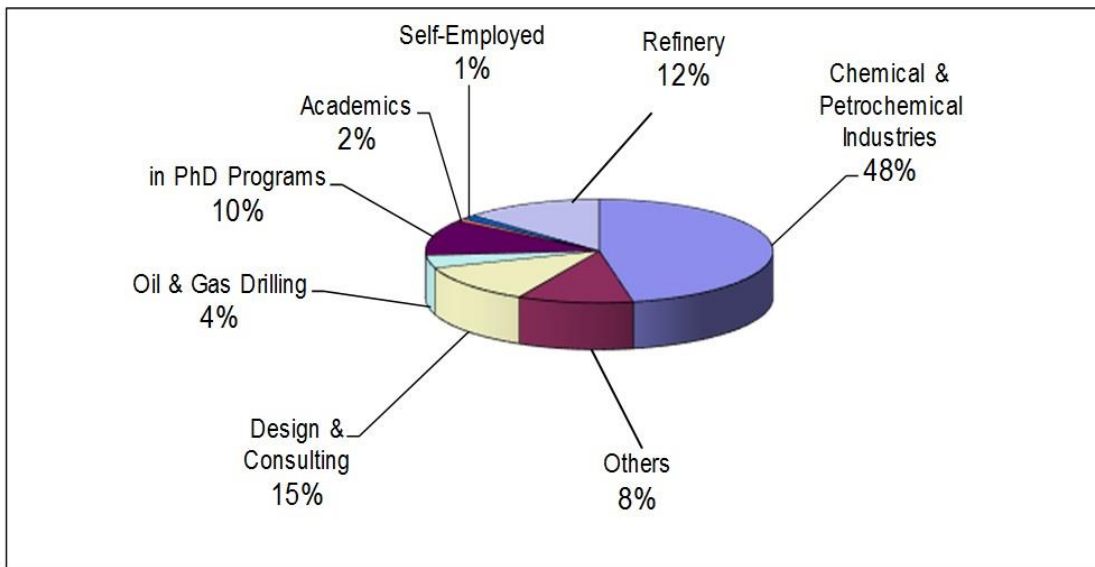


Figure 4. ChEPS Graduates Employment Profile, Class 1 – 17

Finally, ChEPS has complete confidence that site projects are valuable to the sponsoring companies. Some companies such as ThaiOil have openly stated that ChEPS students have over the years helped the company save millions of dollars in costs and energy consumptions. However, most companies are reluctant to disclose such savings figures, and consider all information pertaining to costs, prices, and savings strictly confidential. ChEPS also conducts periodic surveys with site companies and employers of ChEPS graduates, although these surveys tend to be informal. The feedback so far has been positive, and preliminary data show that companies are generally happy with the performance of ChEPS graduates. The strengths of the ChEPS graduates often cited are good English proficiency, good presentation skills, self-confidence, and a short learning curve [8]. The fact that most sponsoring companies continue to make their sites available is a testimony to the benefits and values of the practice school.

4. Other Practice Schools at KMUTT

The success of ChEPS as a conduit for learning has been cited by Technology and Development Program (TDP) at MIT, which works to build research and academic capacity around the world through its assistance in science and technology development [9]. The program considered the KMUTT practice-school endeavor to be its success story in Thailand. At the same time, the practice school model is gaining traction among educators in Thailand, both in higher education and in vocational schools. As a matter of fact, the practice-based learning model originating from ChEPS at KMUTT has inspired the creation of many spin-off programs, both inside and outside the university, in the past 20 years. In addition to ChEPS, KMUTT now has five additional practice-based master's programs, namely

- ❑ Food Engineering Practice School (FEPS)
- ❑ Starch Engineering and Process Optimization Program (SEPO)
- ❑ Bioinformatics and Systems Biology (BIF)
- ❑ Biotechnology Practice School (BIPS)
- ❑ Biopharmaceutical Engineering Practice School (BioPhEPS).

Table 3 shows all the existing practice-based Master’s curricula at KMUTT and their targeted industries.

Practice School	Acronym	Year of Inception	Targeted Industries
Chemical Engineering Practice School	ChEPS	1997	Chemical, Petrochemical, and Petroleum
Food Engineering Practice School	FEPS	2001	Food and Agro-industry
Starch Engineering and Process Optimization	SEPO	2003	Starch and Agro-industry
Bioinformatics and Systems Biology	BIF	2003	Pharmaceutical, Medical, and Biotechnology
Biotechnology Practice School	BIPS	2006	Biotechnology
Biopharmaceutical Engineering Practice School	BioPhEPS	2014	Pharmaceutical

Table 3. Existing Practice Schools at KMUTT

4.1 Food Engineering Practice School (FEPS)

The FEPS program was established in 2001 following the success of the ChEPS program [10]. Like ChEPS, FEPS is also a two-year international curriculum leading to a Master’s degree in Food Engineering. The FEPS curriculum follows the same academic timeline as that of ChEPS and uses the same practice school model. As Thailand derives a substantial amount of revenues from the exports of agricultural and food products each year, more food engineers are needed in the workforce. FEPS was established precisely to meet that demand. The program aims to revolutionize the traditional graduate study and train a new breed of food engineers, who are well-equipped with fundamental knowledge and hands-on experience in the food industry. FEPS graduates are expected to make a significant impact on Thailand’s food industry by innovating food processing technologies, adding values to native produces, and lowering production costs.

While ChEPS students’ background is exclusively chemical engineering, FEPS students have more varied backgrounds, including food science and technology, food engineering, and

chemical engineering. FEPS admits 15 – 20 students every year into its program. FEPS also relies heavily on the sponsorship of the industrial sector for its funding and placements. The following is a list of food companies that have been FEPS' industrial partners over the years.

- ❑ Siam Food Products Public Co., Ltd.
- ❑ Saha Farm Co., Ltd.
- ❑ CPRAM Co., Ltd.
- ❑ Betagro Group
- ❑ Thai Union Frozen Public Co., Ltd.
- ❑ T.C. Pharmaceutical Industries Co., Ltd.
- ❑ Lily Tobeka Co., Ltd.
- ❑ Bangkok Bank (BBL) SMEs

4.2 Starch Engineering and Process Optimization (SEPO)

The SEPO program was established in 2001 to develop human resources for the agro-industry, which is an important industrial sector in Thailand. SEPO is not a degree-granting curriculum, and as such must rely on ChEPS and FEPS for students. Students enrolled in SEPO are actually admitted into KMUTT first as ChEPS or FEPS students. These SEPO students then follow the standard curriculum of ChEPS/FEPS, except for six months in the second year in which they will be interned at a tapioca starch company. Their PBL projects also come from the starch industry. Site projects involve improving unit operations such as drying and hydro-cyclones and process optimization in the production of tapioca starch. In its first year, five students from FEPS are enrolled in SEPO. Cholchareon Co., Ltd., a leading manufacturer and exporter of tapioca starch in Thailand located in the Province of Chonburi, serves as placement for SEPO.

4.3 Bioinformatics and Systems Biology (BIF)

The BIF program is a multi-disciplinary curriculum that combines the technical elements of computer science, biology, and biochemistry. Bioinformatics is the scientific and technical foundation of the human genome project, and promises to play a central role in life science of the coming century. BIF was established in 2003 as a joint program between the School of Bioresources and Technology and the School of Information Technology, and is the first such program in Thailand. BIF combines the strengths of the two schools and courses are taught jointly between the staff from both schools. Students in the program receive comprehensive training in genomics, algorithms for sequence analysis, database design and management, and software engineering and programming, including web-based development. Enrolled students have a background either in computer science or in biology with a few exceptions in engineering.

As a science curriculum, BIF relies on hospital and research laboratories of private institutions and universities as placements for its students in their second year. In the earlier years of BIF, the following institutions in Thailand served as the program's placements:

- ❑ National Center for Genetic Engineering and Biotechnology (BIOTEC) of National Science and Technology Development Agency (NSTDA)
- ❑ Siriraj Hospital, Bangkok, the largest and oldest hospital in Thailand
- ❑ Ramathibodi Hospital
- ❑ Ministry of Public Health

More recently, BIF has established connections with some overseas institutions and universities. As a result, the program is able to send the majority of its students overseas for internship, the first of its kind for KMUTT's practice schools. The following is a list of selected international placements:

- ❑ Technical University of Denmark (DTU), Denmark
- ❑ Chalmers University of Technology, Sweden
- ❑ University of Washington, U.S.A.
- ❑ National University of Singapore (NUS), Singapore
- ❑ Osaka University, Japan

Because of their international exposure, BIF graduates possess excellent employability skills. Consequently, many graduates of BIF went on to work overseas in countries such as the US, Japan, Sweden, Singapore, and Taiwan. In fact, some students also had the opportunities to pursue doctorate degrees in these countries. Therefore, the international linkage of the BIF program is unparalleled and is a role model for other practice schools to emulate.

4.4 Biotechnology Practice School (BIPS)

The BIPS program is a practice-based Master's curriculum in the School of Bioresources and Technology at KMUTT. Biotechnology can be defined as the use or any technological application of living systems and organisms or their derivatives. Products from biotechnology have increasingly play a more important role in our daily lives – from simple applications in food technology, to pharmaceutical therapies and medicines, and to complex applications in tissue and genetic engineering.

BIPS was founded in 2006. The program admits only a few students each year, but follows the practice school model. KMP Biotech Co., Ltd. and BBL SMEs are the two main sponsors from the private sector serving as placements. KMP Biotech is one of the leaders of biotechnological products in Thailand, while BBL SMEs, headed by Bangkok Bank, is a consortium comprising small-to-medium enterprises (SMEs) who are clients of the bank. However, funding for BIPS comes mostly from National Science Technology and Development Agency (NSTDA), a public organization whose mission is to advance and sustain the economic development of Thailand through research, technology development, and the promotion of collaboration between the public and the private sectors.

4.5 Biopharmaceutical Engineering Practice School (BioPhEPS)

The BioPhEPS program was initiated in 2014. In its first year, seven students were admitted into the program, all with a background in chemical engineering. Although the pharmaceutical and biopharmaceutical industries in Thailand are still in their infancy, the sector has a lot of potentials in developing and helping to drive Thailand towards a more knowledge-based economy. Innovations and breakthroughs in pharmaceutical therapies, personalized medicines, and drug development in the past decades have tremendously improved the quality of life and health in old age and increase human longevity across the globe. The current situation in the biopharmaceutical industry is therefore very exciting.

National Science Technology and Innovation Policy Office (STI), an autonomous public agency tasked with producing policies and plans to promote science, technology, and innovation at the national level, provides the funding for BioPhEPS. The BioPhEPS curriculum is an interdisciplinary that includes drug engineering, novel drug delivery and targeting, pharmaceutical technology and analysis, and unit operation of chemical engineering. The focus is on the use of technology on chemical agents in providing better medicinal treatment.

BioPhEPS has two practice stations. One is the National Biopharmaceutical Facility (NBF) stationed at KMUTT's Bangkhuntien Campus in the outskirts of Bangkok. NBF is Thailand's prime manufacturing site for biopharmaceuticals. The unit serves as a center of excellence in science and technology to ensure self-reliance in the country for the production of drugs, vaccines, and other high-value biomedical and biopharmaceutical products. The second practice station is Science Bioscience Co., Ltd., a life-sciences company in Bangkok which focuses on commercialization of both pharmaceutical and biopharmaceutical products. Key products of the company include medicines in the therapeutic areas such as oncology, antiviral, autoimmune disorders, central nervous system, cardiovascular, and metabolic disorders.

Future plans of BioPhEPS include admitting students from more varied backgrounds, such as those in chemistry, pharmaceuticals, bioengineering, etc. Talks are also underway with overseas partners, e.g. with Soonchunhyang University in South Korea, about possible student exchange and research collaborations.

5. Undergraduate WIL and Practice Schools

Before the practice school model was introduced into KMUTT, the university had already had a long history of integrating WIL into many of its academic departments, mainly in the Faculty of Engineering, the Faculty of Science, the School of Information Technology, the School of Architecture and Design, and the Faculty of Industrial Education and Technology. However, all WIL-based curricula are almost exclusively operated at the undergraduate level and run as cooperative education programs (co-op). In addition, no standard operating procedure (SOP) exists for running these co-op programs. Each academic department uses discretion to decide how to implement its co-op program. Some integrate WIL into a selected number of elective courses, while others require that students spend four months working full-time at a placement. In all cases, these co-op programs are not as structured as the graduate-level practice schools,

and there are no dedicated site directors who work closely with interned students. Instead, faculty members from the department visit the placement periodically to follow up on the students' learning and work progress.

In 2010, KMUTT established the WIL Office reporting directly to the President of the university. The aim of the WIL Office is to promote and support work-integrated learning, both at the undergraduate and graduate levels. Moreover, the new office aims at maximizing benefits of the three stakeholders, namely KMUTT, students, and placement companies, which is crucial for the long-term success of WIL programs. WIL is an excellent mechanism for producing students who possess the attributes that industry requires and a channel for strengthening linkage with the private sector. On the other hand, industry can reap direct benefits from the output of students' projects and use WIL as a channel to explore prospective employees. Finally, through WIL, students can improve independent learning which is important to their future professional development.

Specifically, the WIL Office is tasked with the following functions:

- ❑ Establishing guidelines for operating WIL programs based on the practice school model
- ❑ Providing linkage between KMUTT and the private sector to facilitate collaborations
- ❑ Expanding WIL to include more students and curricula
- ❑ Ensuring quality in student learning
- ❑ Maintaining a standard for assessing program output
- ❑ Creating and developing a career path for site directors and facilitators involved in WIL programs

Whenever possible, future WIL-based curricula at KMUTT are to use the practice school model, while the new model will supplant or complement existing co-op programs. Two notable undergraduate practice-based programs are Betagro-KMUTT WIL and Michelin-KMUTT WIL.

5.1 Betagro-KMUTT WIL

Betagro Group has been a very important placement sponsor of KMUTT's FEPS program since 2003. The company is one of Thailand's forefront agro-industry and food businesses, engaged in animal feed production, livestock, and animal health products as well as the production of high-quality food products. Betagro's branded products are distributed and sold across the globe in both local and overseas markets.

After the success story of the FEPS program, Betagro Group felt that it was ready to expand the FEPS practice school model to its other subsidiaries. For many years, FEPS students have focused their attention mainly on solving problems and conducting research related to food technologies and production processes. As a conglomerate, Betagro Group also owns many business units which entail many other technical projects. These projects are no longer confined to food processing, and require skilled workers from diverse backgrounds, such as chemistry, physics, biology, and engineering, to tackle. Betagro realized that KMUTT was in a unique position to assist the company in this endeavor because of the university's available resources

from different departments. As a result, the Betagro-KMUTT WIL program was created in 2013. This new WIL program follows the practice school model which requires undergraduate students participating in the program to spend the summer and the first semester of their 4th year full-time at a Betagro business unit. A site director or facilitator from KMUTT is stationed full-time at placement to supervise the students and the projects. The presence of dedicated staff from KMUTT is crucial because the students in the program are relatively young and require more mentoring and support in non-technical areas than those in the FEPS program. Students make a number of oral presentations to keep the company and KMUTT staff abreast of their progress. Betagro-KMUTT WIL culminates in a grand final presentation presided by the CEO of Betagro Group and attended by a team of KMUTT senior management.

About 25 students from several schools and departments are recruited to join Betagro-KMUTT WIL each year. In general, only a few students from each department join this WIL program. Table 4 shows the schools and their departments from which Betagro-KMUTT WIL students are recruited, while Table 5 shows a list of Betagro’s subsidiaries which serve as placements and the number of projects completed during 2013 – 2015.

Faculty / School	Department
Faculty of Science	Microbiology, Chemistry, Physics, and Mathematics
Faculty of Engineering	Control System & Instrumentation Engineering, Mechanical Engineering
Faculty of Industrial Education and Technology	Industrial Technology

Table 4. Faculties/Schools and Their Departments with Betagro-KMUTT WIL

Betagro-KMUTT WIL Placement	Number of Projects		
	2013	2014	2015
B. Food Product International Co., Ltd. (BFI)	7	10	5
BTG FeedMill Co. Ltd. (BTM)	3	1	1
Better Foods Co., Ltd. (BF)	-	5	4
Ajinomoto Betagro Frozen Food (Thailand) Co., Ltd. (TAB)	-	-	2
Betagro Public Co., Ltd.	-	-	1
Total	10	16	13

Table 5. Betagro-KMUTT WIL Placements and Projects

5.2 Michelin-KMUTT WIL

Michelin Siam Group was established in 1987 in Thailand. The company is a leading manufacturer and distributor of tire products covering a wide range of businesses from passenger car and light truck, truck and bus, motorcycle, earthmover to airplane tires under the brand names “Michelin”, “BF Goodrich” and “Siam Tyre”. Michelin Siam Group operates three tire manufacturing plants, one mold manufacturing plant, and one steel cord manufacturing plant. These companies collectively employ more than 6,700 people.

The Michelin-KMUTT WIL program was initiated in 2009 as a collaboration between Michelin Siam Group and the Department of Mechanical Engineering at KMUTT. Only four undergraduate students starting their 4th year are recruited to join the program which is tailored towards tire design and engineering. Students who express an interest in the program are screened, interviewed, and selected by the company.

The Michelin-KMUTT WIL program consists of one summer and two semesters implemented during the final year of participating students. The summer session is used to train students in safety and fundamentals of tire and mold manufacturing. Michelin-KMUTT differs from the other practice-based programs in that students do not spend five days a week (or full-time) at placement. Instead, time spent (three days a week) by participating students is counted towards the credit hours of two elective courses, namely Tyre/Mold Manufacturing and Tyre Mechanics.

Michelin-KMUTT WIL is unique in that it allows KMUTT students to work closely with three other groups of four students from three other universities in Thailand, namely Kasetsart University (KU), King Mongkut’s University of Technology North Bangkok (KMUTNB), and Prince Songkla University (PSU). Students in Michelin-KMUTT WIL also receive financial benefits in the form of a 10,000-baht monthly stipend and free tuition fee. Another benefit for students under Michelin-KMUTT WIL is that they may receive “return offer” from the company, i.e. they stand a high chance of being employed by the company at the end of their placement.

6. Conclusions

A STEM education model called the practice school was initiated at King Mongkut’s University of Technology Thonburi (KMUTT) in 1997. The model aims at overcoming a number of deficiencies, such as theory application, critical thinking, and soft-skill development, in Thailand’s higher education, particularly in science and technology. Students graduated from practice schools are expected to possess a number of attributes sought by companies and essential in their professional life. The Chemical Engineering Practice School or ChEPS, a Master’s level graduate curriculum, was the pilot program. Since then the model has been adopted by several other science and engineering curricula. More recently, KMUTT created the WIL Office to promote work-integrated learning and ensure that undergraduate curricula adopt the practice school model in their WIL programs. The key success factor of the practice model is the close working relationships among the three stakeholders, namely the university, the industry, and the student, which ultimately entail benefits to all parties. The practice school model has received a lot of attention from both the academia and the private sector and is now considered an educational paragon at KMUTT and at the national level.

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