

A Graduate-Level Science and Engineering Practice School Model in Thailand

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Abstract

Practical training has become an important component in the education of today's engineers and scientists. In today's global economy, engineers and scientists in Thailand play an increasingly important role in enhancing the country's competitiveness. Early in its history, King Mongkut's University of Technology Thonburi in Bangkok recognized the need to strengthen its curricula with industrial training. Since then, a number of science and engineering practice-based graduate curricula have been established, starting with Chemical Engineering Practice School in 1997. Other programs that followed suit included Food Engineering Practice School, Starch Engineering and Process Optimization program, and Bioinformatics. The practice model consists of spending one year of coursework on campus, one semester of thesis research, and one semester of industrial internship at a sponsoring company. The practice school fosters problem-solving skills, planning, teamwork, and communication. In this paper, we discuss the history and the motivation behind the creation of the practice-based programs. The uniqueness and key factors contributing to the success of these programs are identified. A complete timeline and description of the curricula are given including a detailed discussion of the practice stations and funding of the programs. Finally, we provide an impartial assessment of the programs based on its output, feedback from industrial sponsors, and the performance of its alumni in the workforce. Eight years after introducing the practice model, all practice programs at KMUTT are now premier curricula in Thailand, which will soon be combined into one school called School of Science and Engineering Practice in order to leverage the available resources, to better serve the students, and to strengthen its relationship with the private sector. Furthermore, more practice-based curricula in other disciplines such as energy, biotechnology, and manufacturing are being planned. Finally, the Thai government has begun to recognize the critical role of the practice model in higher learning. As a result, the government is now making the practice model one of its initiatives and part of its national policy to develop human resources in Thailand.

Keywords: Practice school; Problem-based learning, Chemical engineering, Food engineering, Bioinformatics

1. Introduction

The traditional method of learning in science and engineering disciplines involves classroom lectures, homework assignments, and laboratory work. Although this training is effective to a certain extent, there exists a gap in the skills of students when they step out into the real world. This is particularly true in Southeast Asia including Thailand, where rote learning is the norm [1]. *Spoon-feeding* is prevalent in classrooms even at the college level, and creative thinking is overlooked. As a result, few graduates in Thailand possess the necessary analytical skills to succeed as scientists and engineers. 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.

In addition, the English proficiency of Thai students in technical fields is on the average subpar. In today's global economy and with a substantial foreign direct investment totaling billions of dollars annually in Thailand [2], 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, as most programs do not have a minimum English requirement

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for graduation. Finally, companies often complain about the inadequate training of university graduates in communication, be it spoken or written, even in their own native tongue. These facts are hardly surprising, given that nearly all graduate programs are taught in Thai with little emphasis on technical writing and oral presentations.

2. Science and Engineering Practice Model

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-based 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 expertise, 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 agencies, the students, and the industrial linkage.

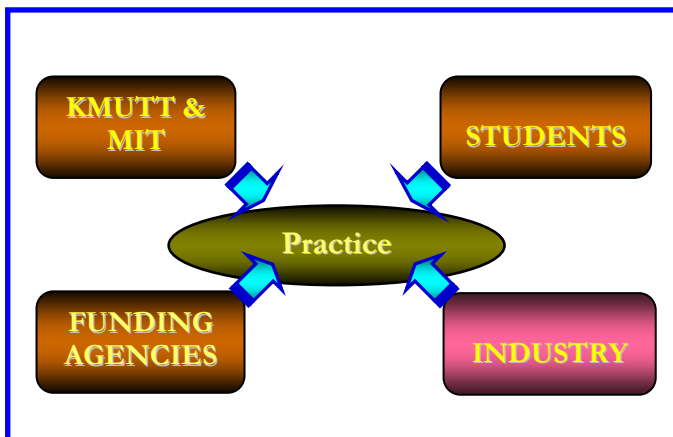


Figure 1. The Four Essential Components of a Practice School

*Proceedings of the 2005 Regional Conference on Engineering Education
December 12-13, 2005, Johor, Malaysia*

The funding agencies are state, semi-private, and private organizations, which provide research grants and scholarships to academic programs. All practice schools at KMUTT have relied heavily on such agencies for financial support in their operations, particularly during the early years. In a traditional graduate program, the industrial component is normally missing or its role is limited. On the other hand, industrial involvements are 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 or solved as site projects during internships.

KMUTT chose Chemical Engineering to be the pilot program and founded the Chemical Engineering Practice School (ChEPS) in 1997 [3]. Once proven successful, this pilot program was in subsequent years succeeded by similar programs in other science and engineering disciplines. Table 1 shows all the existing practice-based curricula, all of which are Master's programs, at KMUTT. A detailed description of each practice program is given in the next section.

Table 1. Existing Practice Schools at KMUTT

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	BIF	2003	Pharmaceutical, Medical, and Biotechnology

2.1 Chemical Engineering Practice School

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 [4]. 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, 18 – 26 students were admitted annually.

2.2 Food Engineering Practice School

The FEPS program [5] [6] was established in 2001 following the success of the ChEPS program. Like ChEPS, FEPS is also a two-year international curriculum and leads to a Master's degree in Food Engineering. 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 and adopt the Thai government's initiative to become the "kitchen of the world". 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.

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.

2.3 Starch Engineering and Process Optimization

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.

2.4 Bioinformatics

The BIF program [7] is a multi-disciplinary curriculum that combines the technical elements of computer science, biology, and biochemistry. BIF is the first and the only one such program to date in Thailand. This relatively new scientific program focuses on the study of biological information, ranging from the vast genetic information being rapidly accumulated, to patterns of protein expression and their links to disease states. 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. Courses are taught jointly between the faculties of the two 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. Since inception, 10 students were admitted into BIF each year. Enrolled students have a background either in computer science or in biology with a few exceptions in engineering.

3. Practice School Curriculum

Despite their varied core coursework and different research emphasis, the curriculum of all practice schools share many common characteristics. A typical practice school curriculum consists of one academic year (two semesters and one summer) of coursework, one semester of research, and one semester of internship at a practice site. The coursework is fairly fixed for ChEPS and FEPS, while BIF students have more electives to choose from. One objective when starting the practice model was to introduce Western-styled learning into Thai classrooms. The practice curriculum emphasizes both problem-solving and intensity. The whole program can be viewed as a *learning factory*, where problem-based learning (PBL) is emphasized and students are constantly challenged to solve real-life problems, sometimes with limited data and many constraints.

Course lecturers consist of both local and overseas instructors, including professors from the US, Canada, Europe, and Australia. Table 2 shows the topics in the first-year courses of each practice program.

Table 2. Course Subjects of the Practice Curricula

The ChEPS Curriculum	The FEPS Curriculum	The BIF Curriculum
Advanced thermodynamics	Food science principles	Molecular Biology
Applied mathematics	Applied mathematics	Data structures and algorithms
Chemistry and petroleum processing	Food engineering principles	Computer systems and programming
Process control and optimization	Process control and instrumentation	Microbiology and biochemistry
Reaction kinetics	Transport phenomena	Molecular biochemistry
Process simulation and modeling	Food process design and modeling	Sequence analysis and annotation
Transport phenomena	Physical properties of foods and biomaterials	Experimental techniques in molecular biology
Engineering management	Engineering Management	Data mining for bioinformatics

Despite the similarities, the KMUTT practice curricula are not exact duplicates of the MIT model. Certain components were added to enhance the MIT model and compensate for common weaknesses in Thai students. For example, ChEPS and FEPS introduced a course in engineering management to enable students to better manage time, people, and projects. Moreover, all programs are lengthened to two academic years and one summer to accommodate the intense workload and schedule of the students. Finally, all practice programs at KMUTT are supplemented with the follow components:

- *Presentations.* Students hone their presentation skills by giving no less than 30 talks by the time they graduate. Presentations are required in every phase of the practice schools, including PBL projects, research thesis, and site projects.
- *A short research thesis.* Every student must pick a thesis project to be completed in 6 months. The extensive networking of all practice schools inside and outside KMUTT, including overseas institutions, allows a student to choose just about any research topic that is of interest to him. 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

Northern America, Europe, and Singapore. While the primary goal of all practice schools except BIF is not to produce researchers, many students find the training useful. The students learn to think critically and analytically and must devise a systematic approach to solve a research problem. In fact, many graduates from the practice schools have gone on to pursue Ph.D. degrees at another institution, both in Thailand and overseas.

- *English tuition.* All programs require that all students score at least 520 on the paper-based TOEFL 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. 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.
- *Special self-improvement workshops.* Students learn to think analytically, critically, and systematically by attending special workshops such as Lego-Logo, Six Thinking Hats, and The Seven Habits. The students generally find these activities useful in conducting research and tackling real-life projects.

In the practice schools, computers and software packages are heavily used to supplement classroom lectures. Many courses offer hands-on workshops that demonstrate applications of the theories taught.

4. Practice Stations

The duration of the practice phase is five to six months. In ChEPS, FEPS, and SEPO, 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, two progress presentations, and a final presentation. Faculty on campus also travels to the site and attends 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 processes. 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 site company.

The practice arrangements for BIF differ somewhat from those of the other three programs. Instead of industrial

plants, BIF students are interned at commercial or academic laboratories, which tend to focus more on research. Moreover, a good number of BIF students are sent overseas for their internships. While there, the students are supervised exclusively by overseas sponsors. However, the students are required to submit formal reports to keep the BIF advisors abreast of their progress. Despite the different internship set-up, the basic concept of practical training in BIF remains the same. BIF students have an opportunity to work with professionals who are experts in their fields and on research problems that have commercial relevance.

It should be stressed that the industrial internship in a practice school is not cooperative study (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 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 company at every level to the practice school, starting with providing 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 systematic and more organized, and is therefore far more efficient than the traditional co-op study.

Practice stations for ChEPS are largely petrochemical and petroleum companies. Examples are Thai Oil Public Co., Ltd., Rayong Olefins Co., Ltd., and Thai Polyethylene Co., Ltd. Food companies which have served as FEPS practice stations are Saha Farm Co., Ltd. and Siam Food Products Public Co., Ltd. Finally, practice stations for BIF are medical research laboratories, either locally or overseas such as those in Singapore and Denmark.

5. Funding the Practice Schools

To remain competitive, all four practice programs offer scholarships and monthly stipends to qualified

candidates. The financial support comes from numerous sources, including funding agencies, sponsoring companies, donations, and loan payback from alumni. Two major financial contributors of ChEPS are Energy Policy and Planning Office (EPPO) and Petroleum Institute of Thailand (PTIT). The mission of EPPO under the Ministry of Energy is to foster energy conservation and promote public awareness regarding energy savings. PTIT is an independent non-profit organization supported by the government, academic and private sectors. PTIT's members comprise of petroleum and petrochemical companies, and the institute's main mission is to assist with the development of the two industries in Thailand in areas of human resource development, information service, and policy and regulatory issues.

Another major funding agency for all four practice programs is National Science and Technology Development Agency (NSTDA). NSTDA is 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

The practice programs in turn offer three types of scholarships to students. Under no circumstances are students required to pay while they study. Those who are not qualified for full scholarships are offered no-interest soft loans, which are to be paid back each month amounting to 10% of their salaries once they start working. Full scholarships are unconditional, while half-scholarship recipients must pay back the other half given out as loans. Together, full and half scholarship recipients account for about two-thirds of the students.

6. Program Assessment

ChEPS, FEPS, SEPO, and BIF are now four of the top academic graduate programs in Thailand. Every year, the programs compete for a finite pool of qualified candidates, and are able to attract top students, owing to the program's uniqueness. The success of the practice model can be judged based on the academic records of the admitted students and the employment profile of its alumni. Academically, admitted students are typically ranked in the top 15% of their respective classes with an average GPA well above 3.0.

About half of the practice school graduates currently work for large chemical, petrochemical, refinery, and food companies. A sizable number also work for small-to-medium enterprises (SMEs), e.g. those in the sugar and starch industries, while BIF graduates generally are employed in medical and pharmaceutical research

facilities. Finally, about 15% of the practice school alumni went on to pursue PhD degrees.

The practice schools also conduct periodic surveys with site companies and employers of their graduates. The feedback so far has been positive, and preliminary data show that companies are generally happy with the performance of these graduates. The strengths of the practice school graduates often cited are good English proficiency, good presentation skills, self-confidence, and a short learning curve. The fact that most sponsoring companies continue to make their sites available is a testimony to the benefits and values of the practice schools.

7. Conclusions

MIT in the US has successfully operated its Master's degree chemical engineering practice school for nearly 100 years. The uniqueness of the practice model lies in the industrial internship, which provides practical training for students. In 1997, KMUTT brought the practice-school model into Thailand as part of a reform initiative to improve the quality of its science and engineering curricula. Thus, the ChEPS program was born, and was quickly followed by the creations of the FEPS, the SEPO, and BIF programs. The four practice programs incorporated the essential elements of the MIT model, but were expanded to reflect the needs of Thai students. Problem-based learning and work intensity, together with industrial involvement, are the keys that drive the students to excel and contribute to the success of these programs.

ChEPS, FEPS, SEPO, and BIF have since established a reputation as premier academic programs Thailand. Each year, hundreds of applicants compete for a limited number of openings. Admitted students are generally ranked in the top 15% of their graduating classes. Surveys have shown that companies sponsoring the practice schools believe the practice model to be a win-win partnership. Feedback from companies who hire alumni of the practice schools is also generally positive.

The success story of the practice model at KMUTT has gained widespread attention among educators. The Thai government has also taken note and will be introducing a new initiative to make the practice school a new model of learning in higher education in order to enhance the country's competitiveness and develop its human resources. For its part, KMUTT is currently planning to combine all four practice programs into a new school called School of Science and Engineering Practice (SSEP). The goal is to leverage the available resources, to provide a one-stop service for applicants, to seek more

funding, and to strengthen linkage with the industries. Finally, it is expected that more practice-based curricula in other fields such as energy, bioengineering, and manufacturing will soon be established within SSEP.

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