Dual System Curriculum in Chemical Engineering Education

Abdul Halim[a,*]

[a]Department of Chemical Engineering, Universitas Internasional Semen Indonesia, Jl. Veteran, Sidomoro, Kebomas, Gresik, 61122, Indonesia

*Corresponding author: abdul.halim@uisi.ac.id

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ABSTRACT: Higher education for chemical engineering is required to fulfill several aspects of the required skill and knowledge requested by stakeholders, including professional societies, company partners, accreditation boards, and national standards. Ministry of education of Indonesia under Makarim administration also mandated more liberal practice in Indonesian higher education as jargoned as "Merdeka Belajar Kampus Merdeka (MBKM)" means "freedom to learn, freedom campus". These several aspects, combined with the current COVID-19 pandemic, bring a massive problem in the curriculum. Herein, we discuss and propose a dual system curriculum to accommodate the government standard's requirement, minimize the gap between education and industry, and the professional association. The initial implementation in two universities is observed and the challenges, future direction, and lessons learned are discussed. We expect the curriculum gives the student experience learning in the classroom and a live laboratory in conjunction with MBKM's spirit.

Keywords: Curriculum, dual system, chemical engineering, Indonesian higher education

INTRODUCTION

The gap between university education and professionals is frequently found [1–3]. Higher education is expected to be an interface between professional and educational, even though education is more than teaching and training students to be ready with the industrial requirement [4]. However, minimizing the gap between academic and professional is essential because the majority will enter the workforce after finishing their studies in college [5]. To minimize the gap, the university could facilitate industrial training for the student through the internship program. The internship has become a part of the curriculum; however, these internship hours are still minimal[6–8]. The internship to a particular industry also lacks professional training because of no standardized guidelines for the industry mentor to train the internship students.

Otherwise, the knowledge pace in the industry and the academics is quite different, resulting in the university's education being far from practical. In addition, global issues such as nanotechnology, industry 4.0, and sustainable and environmentally friendly businesses need a new curriculum concept. The nanotechnology issue has decreased than a decade ago, but the technology is not totally established in Indonesia. Nowadays, the industry 4.0 issue rises, and almost all the university try to adopt this issue. Simultaneously, sustainable and environmentally friendly efforts generally focus on individual courses [9], or even these courses are elective. These three global issues are usually included in the elective or partial in the curriculum.

Figure 1 shows the input components need to accommodate in the Indonesian chemical engineering curriculum. The institutions need to accommodate five inputs, as shown in Figure 1. First is the mandatory national standard. As Indonesian legislation and administration ties to all higher education institutions, the institutions must accommodate and fulfill the government's minimum standards. This standard includes three standards: the national standard for education, research, and community service [10]. Simultaneously, higher education also must follow Kampus Merdeka policy, where students have more liberal and free administration about what type or method of learning they desire. For instance, the research thesis could be equivalent to a research competition funded by the ministry of education. Students can also easily take a course outside their study program or department or even outside the university [11]. This practice is common practice in the US or Japan but, uncommon in Indonesia, brings a broad perception. Ironically, many universities recognized courses taken from foreign universities by dual or double-degree treaties between Indonesian universities and foreign universities [12].

The second is the professional standard; in this case, a professional association such as PII (Indonesian Engineer Association) might have a chemical engineering curriculum standard. This practice has been implemented in medical education [13]. International accreditation standard is from the Indonesian Accreditation Board of Engineering Education or other foreign accreditation board such as the Accreditation Board for Engineering and Technology, USA, or Institute of Chemical Engineer, the UK. Many universities are eager to receive international recognition, so they need to implement international standards such as the Washington accord. Industry partner standard, especially for the students under the agreement to work for industry partners after graduation. The curriculum needs to accommodate these all inputs. The suggestion and critics from stakeholders, including industry partners, alumni, professional associations, parents, public and global issues, are also an input for the curriculum (Figure 1).

FIGURE 1. Standards need to accommodate in the curriculum.

Here, we think that a dual system adapted from the German vocational system can accommodate all of those requirements even though its initial intention is to vocational education. The dual system program is an educational program that the education institution collaborates with companies to offer courses that combine academic and vocational learning. The dual system curriculum has been applied to German vocational schools. Many perspectives and research on the dual system have been introduced [14–19]. Garcia [20] proposes a dual-system concept to the Industrial Design Engineering curriculum that complements the Spain education system. The dual system is believed to solve the gap between education and professional gap and increase the employable rate after graduating [19]. This article will explore the possibility of adopting part of the dual system concept for the academic pathway of the higher education curriculum.

RESEARCH METHOD

We studied qualitatively through field and case studies compared to the literature. We observed and compared the policies of several study program curriculums in several universities. The meeting documents from Institut Teknologi Sains Bandung (ITSB) and the Swiss International Technical Connection (SITECO) as the major dual system institution in Switzerland were studied and discussed with stakeholders. The policies and the feedback of enforced policies were listed and discussed. Then, the conclusions were derived to draw a new concept of curriculum for chemical engineering.

PROPOSED CURRICULUM

Figure 2 shows the diagram of the proposed curriculum. There, the curriculum is not described in detail because of its divergence in the Indonesian chemical engineering study program. It allows the concept to be flexible enough to be adopted by an extensive range of institutions.

Year	Freshman		Sophomore		Junior		Senior	
Semester	1	2	3	4	5	6	7	8
Pathway 1	University				Company Internship		University	
Pathway 2	University							
Courses	Basic natural sciences Basic social sciences Programming		Major courses Programming		Applied major courses Advanced courses		Research Business	

FIGURE 2. The schematic diagram of the proposed concept.

Freshman

During freshman year, the students will learn the basic social science and humanities, including the compulsory course by the national standard such as religion, Indonesian language, English language, and citizenship. Basic natural science will be the fundamental of major courses (Figure 3). Basic natural science includes fundamental calculus, fundamental chemistry, fundamental physics, and biology, especially fundamentals of microbiology or biochemistry. The programming skill must start from a fundamental aspect such as how computers work because many Indonesian high school students, especially from an underrepresented background, do not have access to the computer. Therefore, it is essential to increase the proportion of programming or computer-related course hours. This strategy is also to overcome the lack of breakthrough findings by Indonesian researchers due to the lack of fundamental aspects[21–23].

Basic natural sciences	Basic social sciences	Programming
• Fundamental chemistry • Fundamental physics • Mathematics • Fundamental microbiology	• Indonesian literature • English language • Citizenship • Sport and art	• Basic computer science

FIGURE 3. The list of courses in the first year

Sophomore

Students will receive the core major of their course more frequently in the second year (Figure 4). This year, they will receive a concept of thermodynamics, chemical reaction, transport phenomena, numerical modeling, and organic and biochemistry. Students are expected to solve complex problems numerically with the programming skills they received during the first year. The programing course will also focus on the applied and problem solving of the chemical engineering problem. The organic and biochemistry course discusses polymers and biochemistry fundamentals related to the industry.

FIGURE 4. List of courses in the second year

Junior

This year the course is more industrial or emphasize application aspect such as unit operation (Figure 5). The typical unit operation such as separation units, mixing units, reactor units, and transportation units are introduced for specific or several types of industry. For instance, a reactor unit could be a rotary kiln for the cement industry or a digester for the pulp industry. This year students have an option to accomplish their Junior year in the university or the partner industry. Students who intend to take a residential option will receive training in the industry from operator level to managerial level. University lecturers and industry trainers have to collaborate and make sure they receive a minimum standard of the course. The contribution of lectures or trainers has to be clear from the beginning. For instance, the lecturer will deliver theoretical aspects. Simultaneously, the trainer will train the student on how to apply this theory to actual engineering problems. This schedule must be discussed together with the industry partner. Lecturers can use online platforms [24] to deliver theoretical aspects to students if the classroom and industry's location are quite far. For those who want to accomplish their Junior year in university, the course is similar except they receive the training in the university and some skills are gained in the laboratory.

A short survey from prominent chemical engineering departments in Indonesia such as ITS [6], ITB [7], and Unpar [8] shows a lack of biology and programming courses. Therefore, increasing those courses learning hours is important because the technology trend shifts from microscale to nanoscale and biology to obtain more sustainable, eco-friendly, precise, pure, and efficient processes. The use of machine learning for predicting the structure or synthesis mechanism has become a trend. Otherwise, enzyme, protein, and genetic engineering are not only become a domain of biologist or a chemist, but the chemical engineer also needs to gain a practical skill and knowledge for industrialization of the genetical engineering product.

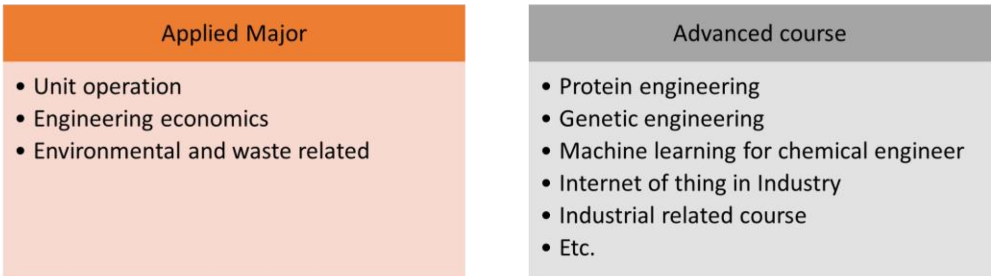

FIGURE 5. List of courses in the third year.

Senior

This year students focus their research on the laboratory. Students who wish to pursue a graduate school will gain the training this year (Figure 6). They also learn managerial, leadership, business and take the advanced class to specialize in their major. From industry training, they also will get more idea how to solve the actual problem in the industries and bring them to the laboratory. This process will be a win-win solution to the research gap between university and industry. The supervisor from the industry usually comes from a broad educational background. The students will be benefited from learning how to design, and the other things related to the supervisor's educational background, such as unit operation maintenance. Students also learn the specific industry or topics, such as pulp and paper industry, combustion, ceramics, nanotechnology, industrial waste, and cement industry, equivalent to the elective courses. Students will also get training experience on being effective leaders, managing problems, and anxiety during their training in the industry. The learning activities are active learning instead of instructor-centered learning[25]. After the student came back to the campus, they will be trained on how to do research. Lecturers will get benefit from what students bring from the industry.

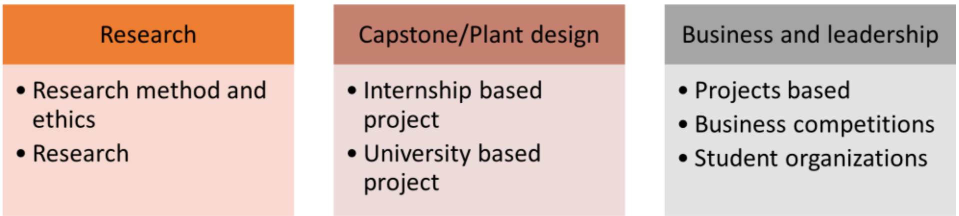

FIGURE 6. List of courses in the fourth year.

LESSON LEARNED FROM THE IMPLEMENTATION IN UNIVERSITAS INTERNASIONAL SEMEN INDONESIA (UISI) AND INSTITUT TEKNOLOGI SAINS BANDUNG (ITSB)

Universitas Internasional Semen Indonesia (UISI) is a private university under the Semen Indonesia Foundation. The university keeps tight to the Semen Indonesia group, one of the largest cement producers in Indonesia. The university has four years of academic bachelor in the chemical engineering program. Institut Teknologi Sains Bandung (ITSB) is a private university under ITSB foundation. The institution is supported by Sinar Mas Group, one of the largest palm oil, pulp, and paper producers. The ITSB has four years program of vocational bachelor in pulp and paper technology. The pulp and paper technology program curriculum is a specialization of chemical engineering curriculum focusing on the pulp and paper industry.

The universities offer dual system programs with two different methods. The UISI offers a program through the certified internship program (PMMB) from 2019. Students who are interested in joining the program can register at the student office. If they are selected, they have several options. First, they must furlough because they cannot attend the offline class. Second, they can convert the program to a particular class. The process is depicted in Figure 8. The students need to consult with each class teacher they want to convert. The class teachers will map the learning outcome based on the program then list the additional activities to achieve the learning outcomes. Depending on the students' condition, this process might make only a few classes that can be converted for Junior year. Therefore, the students are forced to drop another class they cannot attend, making them take fewer classes then potentially postpone their graduation. However, the senior year students might complete all or most compulsory credit and remain only a few classes to attend. In this case, they neither need to furlough nor drop another class. If the senior year students still have several compulsory credits, the furlough or graduation delay might be unavoidable. The process is described in Figure 7.

The UISI method is relatively effortless because the class teachers can take account case by case and depend on the subjectivity of each class teacher. Some class teachers might be mapping the program in detail. However, the other might just convert the students' score from industrial supervisor to the class score. The advantages and disadvantages of these practices are described in Table 1.

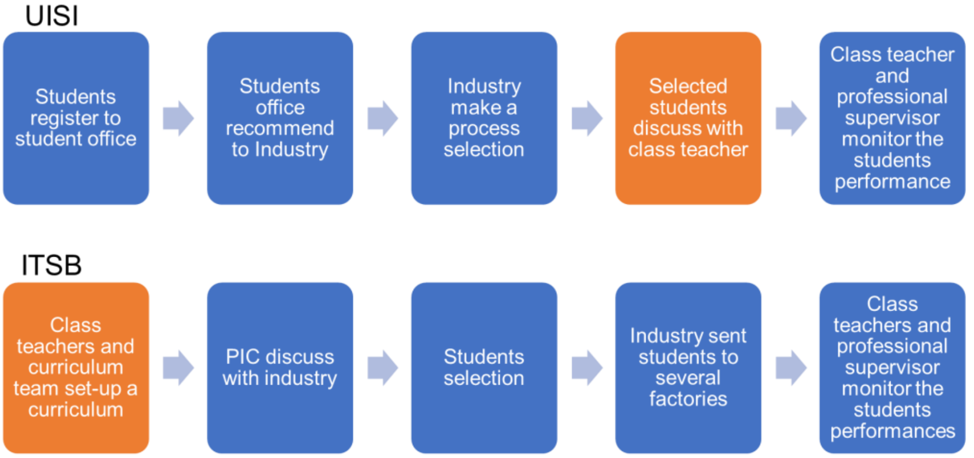

FIGURE 7. The difference between UISI and ITSB dual system.

In contrast, ITSB mandate the students to take the PMMB programs in several plants of Sinar Mas Groups. The students are sent to the plant for three semesters. The curriculums are set to accommodate the minimum requirement of pulp and paper association on level 5 from 9. The learning outcomes include the minimum learning outcomes from the partner industry learning center. The person in charge will contact the industry learning center to plot the students. The industry learning center will coordinate with the human resources of the plants then place the students. Here, the student will be advised by one industry advisor, and the students will consult with the teachers to achieve the minimum learning outcome. Students neither need to take furlough nor postpone their graduation because the learning outcomes have been set up from the beginning with the industrial partner. However, because of the variety of industries, the setup process requires more effort and is unlikely to accommodate all of the requirements. The advantages and disadvantages of these practices are described in Table 1.

TABLE 1. Advantages and disadvantages of two different approaches

UISI		ITSB	
Advantages	Disadvantages	Advantages	Disadvantages
Minimal effort for curriculum setup	The placement might be different or difficult to displace some learning outcome	Several scenarios in the industrial training have been set up, therefore the placement is more likely to comply with learning outcome	The university might need to build a teaching laboratory to give students similar experience or skill
Suitable for university without a tie to industry	Only a few classes can be converted	One semester class can be converted	Might not comply with MBKM policy if the process is mandatory
More likely comply with MBKM policy	Depending on the subjectivity of the class teacher	The guideline has been set up. Therefore, the subjectivity can be minimalized	More effort during curriculum setup

CHALLENGE OF CURRICULUM IMPLEMENTATION

The contribution of the university to the professional engineering education

Indonesian legislation and the president's administration describe three kinds of educational pathways: professional, academic, and self-learning called KKNI (Kerangka Kompentensi Nasional Indonesia) [26–

28]. Professional education is achieved from training in the company or profession-related activities. The academic way is achieved by formal education in schools, institutes, colleges, or universities. At the same time, self-learning is achieved by self-training. Some professional education collaborates with universities for certification, such as the Indonesian Medical Doctor Association (Ikatan Dokter Indonesia). Medical schools must collaborate with a qualified hospital to conduct medical doctor trainees or specialists. In the engineering area, Indonesian Engineering Association (PII) has collaborated with a qualified engineering university to certify the engineering profession as a mandate by legislation [27]. However, nowadays, most universities conduct the professional program through the Recognition of Prior Learning (RPL) program which means universities do not directly contribute to students' technical training. Indonesia legislation mandates that only higher education reserve the right to conduct and give a professional degree at any level. Therefore, this dual system can be an initiator for further advancing Indonesian engineering education and the RPL program. Collaboration between professional associations, industry, and universities becomes essential and inevitable.

Online learning

On the other hand, industrial digitalization and COVID-19 bring education into more internet bases. Indonesia's government has encouraged many education levels to prepare for the Industrial Revolution and encourage including it in the curriculum. Some department has a specific fund to answer these challenges. Unfortunately, several universities still lack facilities and access to funding sources. However, a commercial platform such as youtube can be utilized and developed.

Research collaboration

With more collaboration between university and industry, the research idea and topic can be more appropriate, especially for applied research. This collaboration will also help the university to receive access to private research funding. Besides, because funding from the government mandates industry partners, this collaboration will solve the problems.

Teaching Industry Establishment

A University that ties to a company or is established from the CSR of a specific company will be easier to access or minimal has more chances to collaborate with the industry. However, public universities, even the well-established university, still lack education collaboration. In this case, well-established and large funded universities can build a teaching industry. The teaching factory can facilitate economic and technical training programs so that students from any major receive benefit from this establishment. Universities can involve students during establishment and operation. With many professors and professional human resources in the university, the establishment is not a daydream. One of the initial starts is the independencies of wastewater treatment and energy/electricity. University initiates to build a company either energy, waste processing, water treatment by themselves. Instead of depending on the city facilities, the university could focus its human resources to build a company that will be used as a teaching company and gain revenue.

CONCLUSION

A dual system curriculum might be applied in the academic curriculum and conjunction with all of the minimum requirements requested by stakeholders. This curriculum could be a positive effect on the students, especially in their industrial or professional skills. However, to implement the curriculum, some challenges and requirements need to be overcome.

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