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# INTEGRATING PROGRAMMING SKILLS IN CHEMICAL ENGINEERING CURRICULUM FOR STUDENTS WITH LOW TO MODEST ACADEMICS PERFORMANCE TO COMPETE IN INDUSTRY 4.0

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**Abstract**

Chemical engineering is a field of study with complexity due to the requirement of students to master multidisciplinary subjects of mathematics, chemistry, physics, and biology. In the industry 4.0, the requirement is even more demanding where programming skills of students are used as to measure their mathematical skill, logical skill, and creative problem solving. Chemical process industries are involved in dealing with the tasks of processing large pool of operation data to optimize the processing facilities. Those tasks are laborious and consume indefinite time if being worked manually. Modeling and optimization software's have been developed to tackle those issues. A few of chemical engineering department of higher education in Indonesia teach the use of modelling and optimization software to students. Some causes have been identified to why modelling and optimization are not widely and intensively taught. One of the causes is the lack of mathematical preparedness of the students. This paper aims to disseminate strategies of teaching modelling and optimization in chemical engineering for students with low to modest academic performance.

***Keywords***: Chemical Engineering, Modelling, Optimization, Teaching Strategies.

## 1. Introduction

Chemical engineering has contributed to the development of human civilization since the 20th century by the invention of materials and technologies in various fields as energy, food, chemicals, petrochemicals, oleochemicals, and many others. Today, the challenge of fulfilling people needs remains the same, yet chemical engineers are facing greater challenge due to the increasing cost of energy, global competition in product pricing and quality, and stringent environmental regulation (Edgaret al, 2001; Sadhukhan et al, 2014). It is widely agreed that invention has shaped the modern society, however it comes with negative consequences to the environment (Sadhukhan et al, 2014). The burning of fossil fuels by cars and power generation plants emits green house gases to the atmospheres causing global warming. Operation of industrial facilities produce waste stream. Invention of new processing technologies, production of environmental-friendly materials and applying of process intensification are the strategies to address the issues. Process intensification aims on major improvements in manufacturing and processing by reevaluating and redesigning existing operation into new operation that are more precise and efficient (Segovia-Hernandez and Bonilla-Petriciolet, 2016). Process intensification in industries refers to efficient-use of resources and minimizing waste streams (Segovia-Hernandez and Bonilla-Petriciolet, 2016).

In the context of globalization and sustainability, one of the main objectives of chemical engineering is to implement multiscale application of computational chemical engineering modelling and simulation to real-life situations (Segovia-Hernandez and Bonilla-Petriciolet, 2016). As the capability and access to computer has increased, the magnitude and the degree of complexity of problems that can be solved by optimization techniques has also expanded dramatically. Typical problems in chemical engineering process design or plant operation involves with multi-solution rather than single solution in which process optimization concerns on synthesizing the best solution by efficient quantitative methods. Survey conducted to recent alumni of Midwestern University's College of Engineering revealed that mathematics, data analysis and engineering tools were categorized as important of ABET (Accreditation Board of Engineering and Technology) competencies in their professional experience (Kinnunen, and Malmi, 2006).

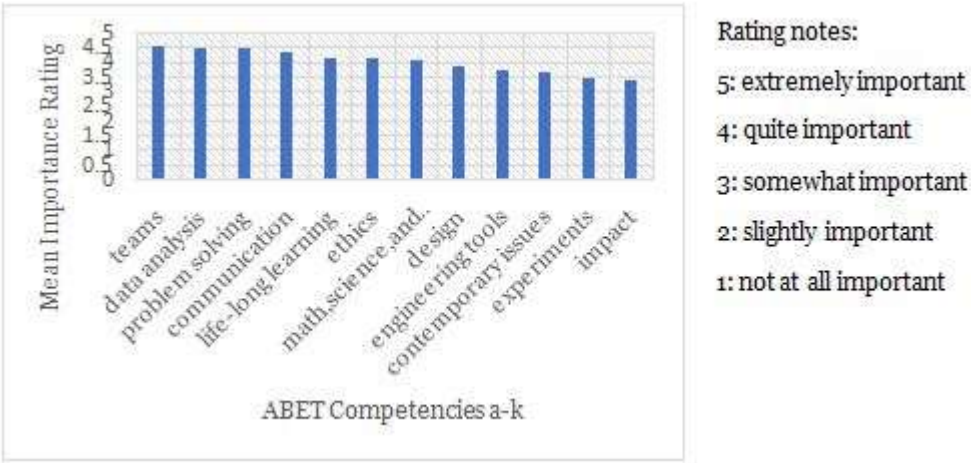


Figure 1: Important Rating for the ABET Competencies from
Survey of Alumni of Midwestern University's College of Engineering [4]

Chemical process optimization involves vast knowledge in process and equipment design and sizing, mass and energy balance, mathematical skills, and computational skills. Teaching computational and programming skills for chemical engineering students requires planning and consistency. Even for students in computer science program, learning programming is difficult. Many institutions in Finland have reported that the drop our rate of students in the class of introductory to programming is about 20-40%. In a specific case in Helsinki University of Technology (HUT), the dropout rate of introductory course of computer science is compulsory is around 30 – 50%. Many factors played in causing the high dropout rate: student's preference of study, lack of motivation, and poor learning skills [5]. This paper aims to propose a design for an elective course in advanced process optimization for students of Chemical Engineering Study Program of Universitas PERTAMINA.

## 2. Background and Motivation

Programming promotes logical reasoning and ability to solve complex problem. Thus, it is very relevant to the study objectives set by ABET. In common practice, chemical engineering undergraduate study program in Indonesia places the modelling and optimization skills as a complementary. Basic programming is integrated into some designed courses, but with low percentage utilization of optimization techniques and will not be able to equip graduates with optimization skills needed in industrial work setting.

According to the data of Indonesian National Accreditation Boardfor Higher Learning (BAN-PT), there are 63 institutions, both public and private, who offer bachelor degree program of chemical engineering. Thirteen achieved A rating, 34 with B rating, and 16 with C rating.

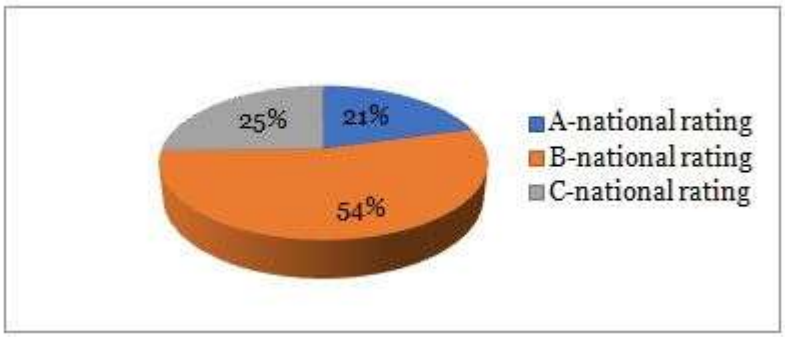


Figure 2: Percentage of Chemical Engineering Study Program Accredited by BAN-PT

Thousands of students graduate each year and compete for employment. Differentiation of our graduates is needed in order to provide the graduates with more opportunity of employment . Optimization is a valuable skill to equip our graduates and to differentiate them from others. The chemical engineering curriculum in Universitas PERTAMINA offers courses with accompany use of MATLAB in the 2nd and 3rd year. MATLAB is used in course of algorithm; numerical method; reaction engineering; and process control.

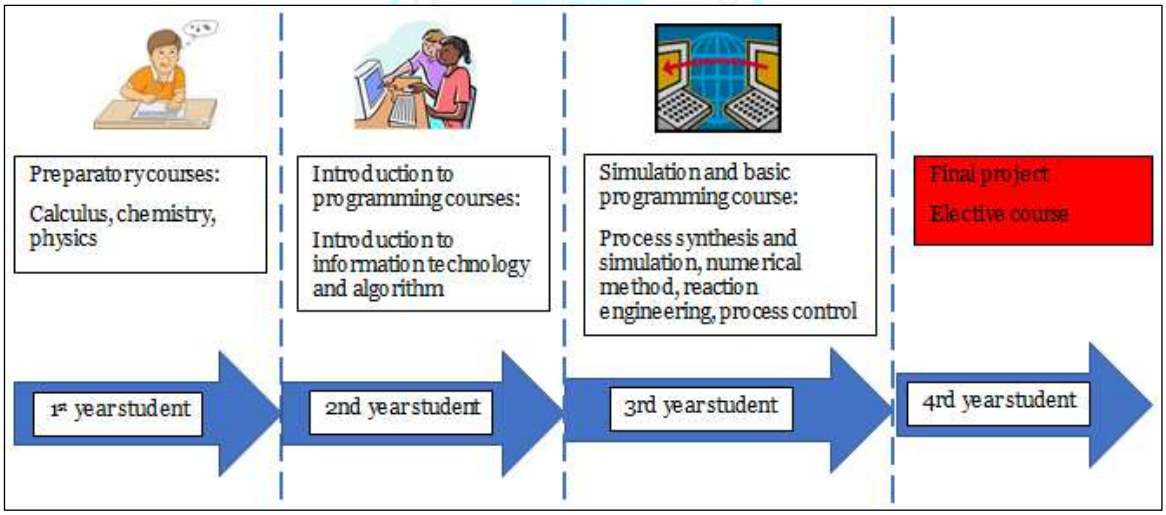


Figure 3: Mathematics and Basic Programming Allocation in the Chemical Engineering Curriculum of Universitas PERTAMINA

The current designed chemical engineering curriculum only facilitates students on the basic skills of numerical computation but yet integrates course of process optimization. Coupling the chemical engineering knowledge with programming skills favors our graduates for competition in industry 4.0 since advanced level of digital tool is one of its cores.

## 3. Literatures Study

The development of softwares and hardwares of information and communication technology (ICT) spreads the euphoria of young generation to learn programming. Responding to this rapid-growth of interest and to ensure the regeneration of young talents in ICT industries, global

communication and technology enterprises such as Google, Amazon, and Microsoft, have supported initiatives to introduce and to teach programming to children through platform of Code Club, Code academy, and Code.org Santos et al, 2018). Through learning programming, children will be trained to analyze simple problem and find the solution through logical reasoning. Higher education institution in chemical engineering should also seek opportunities to integrate and allocate more percentage of teaching computation and programming for undergraduate students.

**Integration of computation and programming in chemical engineering courses**

Several universities have attempted to utilize simulation and programming software into chemical engineering courses. Undergraduate students in Taiwan were taught a process control course with Simulink (Lee,& Chen, 2017). Process control is a mandatory course for chemical engineering students. Syllabus and teaching method for process control course may vary among higher education institutions. MATLAB is commonly used to facilitate the graphical response for simple control architecture.

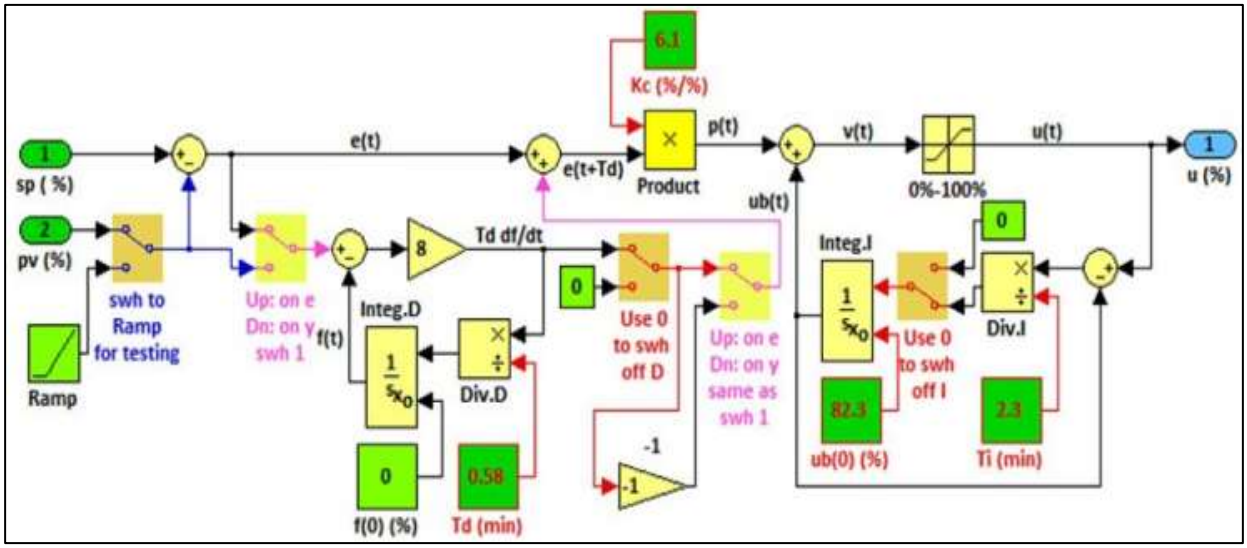


Figure 4: Partial-Integral-Derivative (PID) Control Configuration in Simulink[2]

The study suggests that Simulink® can enhance the students understanding of process control. Chemical engineering faculties in Hongkong University of Science and Technology (HKUST) integrated Excel Visual Basic for Application (VBA) programming to solve relevant projects selected from the chemical engineering core courses(Wong, & Barford, J,2010).Benefits of integrating the Excel VBA programming are students not only able to write program, but also have the ability on solving specific problem and ability to synthesize a chemical engineering problem into a converge program(Wong& Barford,2010). It is argued that teaching how to use Excel VBA in solving chemical engineering core courses assignment is more effective and beneficial compare to teaching programming language to chemical engineering students who will not use it in their future industrial-work setting(Wong& Barford, 2010).

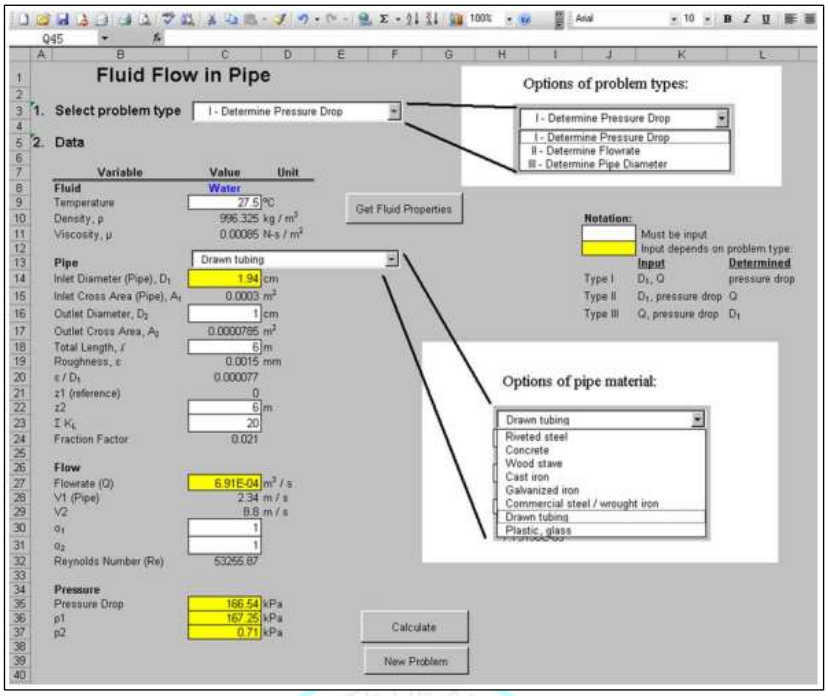


Figure 5: Input Interface for Fluid Flow in Pipe in Excel VBA[8]

The integration of Excel VBA programming into the course received positive feedbacks from students on the relevancy of Excel VBA programming for the particular course and application of Excel VBA programming in their remaining chemical engineering core courses(Wong & Barford 2010).

**Multi-objectives optimization (MOO) application in chemical engineering**

Multi-objective optimization has been studied for its application in the field of chemical engineering. The application of MOO includes process design and operation; biotechnology and food industry. It also includes petroleum refining and petrochemicals and pharmaceuticals and other products/process. Followings are notable works on MOO for respective fields.

Table 1:Notable Works on MOO Application in Chemical Engineering

| No | Area of application | Application | Objective |
|---|---|---|---|
| 1 | Process design and operation | Plant-wide waste management | Superstructure generation and optimization for multiple objectives of solvent recovery from a mixture of acetone, benzene, ethylene dichloride and toluene |
| | | Heat exchanger network | Minimization of annual cost and the composite environmental impact |
| | | Multi-product batch plant | Minimization of investment and number of different sizes for unit operation |
| | | Multipurpose batch plant | Three cases with objective 1) maximize the throughput 2) minimize the number of equipment units 3) minimize the number of floors the reaction mixture has to be pumped up |

| | | | |
|---|---|---|---|
| | | Distillation unit | Simultaneous minimization of total annual cost and potential environmental impact |
| 2 | Petroleum Refining and petrochemicals | Industrial steam reformer | Minimization of methane feed rate and minimization of the flow rate of CO at the reformer exit |
| | | Fluidized bed catalytic cracking unit | 1) Maximization of gasoline yield 2) Minimization of air flow rate 3) minimization of percent of CO in the flue gas |
| | | Scheduling of refinery process | Maximization of total profit while minimization of environmental impact |
| | | Terephthalic acid (TA) production | Maximization of feed flow rate while minimizing concentration of 4-carboxy-benzaldehyde-intermediate in the crude TA |
| | | Styrene production | Five cases using two or three objectives from 1)maximization of styrene production 2)maximization of styrene selectivity 3)maximization of styrene yield 4)minimization of steam used |

*Source:* Rangaiah, G.P., 2017

**Proposed elective course on process optimization using GAMS (General Algebraic Modelling System)**

Integrating programming skills in chemical engineering curriculum is of interest since programming skill is the necessity for process optimization. Programming requires chemical engineering students to master mathematics and the ability to derive physical and chemical phenomena into mathematical notation. The course was designed to facilitate students on not only to be able to write program but also on solving complex problem.

The typical chemical industrial cases usually involve optimization with multiple-objectives. It means that to achieve the optimum for a certain objective requires some compromise on one or more other objectives. Conflicting objectives occur in industry, such as quality over price; operating cost over capital cost; profit over environmental impact, etc (Rangaiah, 2017). The multi-objective optimization is also known as multi-criteria optimization. In order to equip students and graduates of chemical engineering study program of Universitas PERTAMINA, a new elective course in process optimization is proposed. This elective course is designed to be taken by final year students in the $7^{th}$ or $8^{th}$ semester. GAMS software will be used in this process optimization process. The class will be divided into several groups consisting 2 students/group. Two major assignments on optimization will be given where $1^{st}$ assignment dues to a week prior to midterm exam and $2^{nd}$ assignment will be given after midterm and dues to one week before final exam. A library of optimization study cases is available in various textbooks. Assignments can be taken from various textbook with case selection of GAMS application in petroleum refinery. Example of first assignment is optimization for pooling and blending problem in petroleum refinery[9]. In petroleum refineries, final products are often made by mixing fuel from pools or feed streams with different octane number, sulfur content, and/or density. The objective of this optimization problem is to maximize profit by minimizing cost and maximizing revenue.

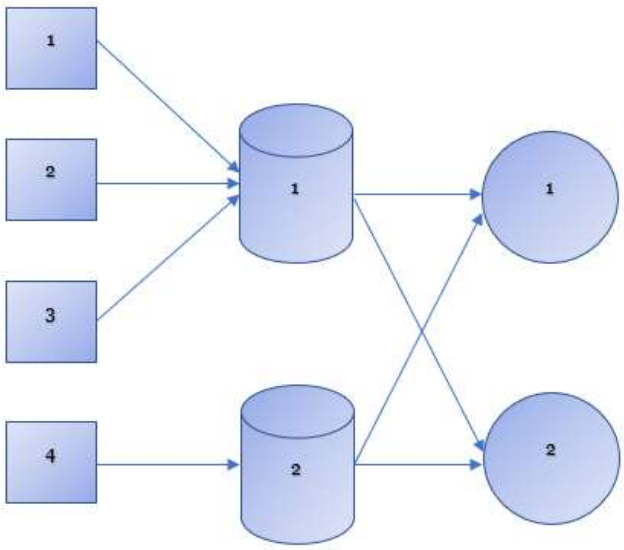


Figure 6: Simplified Schematic Showing of Pooling Network in Petroleum Refinery[6]

Each group required to present their optimization result before midterm exam for the 1st assignment and before final exam for the 2nd assignment. Creating groups of students for the assignments will also develop team-work skills and growing responsibility to working in finishing the assignment.

## 4. Recommendations

The study outcomes set in the proposed elective course of process optimization with GAMS will be accomplishable when basic programming is implanted in relevant chemical engineering core courses in continuous fashion. Basic programming can be taught using visual basic, matlab, and polymath. During the class of Engineering Mathematics 1, chemical engineering students in Universitas PERTAMINA were taught how to solve ordinary differential equation and system of differential equations. Most of them were able to solve the differential equation, but they were lacking the analysis ability. When they were asked to graph the solution of differential equation using excel or other tools they knew of, they just copied whatever graph produced by the computational tool without further analyzing the maximum y values; minimum y values ; x when y reached zero ; and x when y reached infinity. Some students even drew graphs using hand which was laborious and time-consuming. It indicates the necessity of continuous exposure of computation tools.

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