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Teaching Elective Subjects for Junior Students in Chemical Engineering: A Case for Chemistry and Technology of Coal

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The advancement of coal processing challenges academics to prepare chemical engineering students with an ability to apply knowledge of science and engineering in the field area of processing and technology of coal. Since coal is a fossil-based fuel that has negative perception of not being environmentally friendly, teaching these topics to students must be accompanied by more insight and awareness on developing clean coal technology from environment and economic point of view. This paper reports an analysis on teaching “Chemistry and Technology of Coal” elective course that is incorporated in 2013 Curriculum of Chemical Engineering Program, Faculty of Industrial Technology ITB, Accreditation Board for Engineering and Technology (ABET)-accredited program. This course is implemented for junior year students, and focuses on Student Outcomes ability to apply (a) science and engineering, (c) design, (g) communication skills, (h) impact of engineering of economy, environment and society, and (i) life-long learning. The Student Outcome analysis from year 2014 and 2015 is presented. The course comprises a series of lectures, number of discussions between students that encouraging oral and communication skills, and student papers at the end of the class. The feedback from students at the end of the semester suggests that this course is helpful for them to have good basis knowledge about coal processing and clean coal technology, and further improvement is needed for better learning and teaching this area.

1. Introduction

The demand of coal as the primary fuel for generating energy has been increasing. Despite the increasing use and the application of renewable energy, the demand in coal is still strong as the result of ever increasing energy demand. Based on the report by IEA (IEA, 2013), Southeast Asia’s energy demand has increased by over 80 % between 2013 and 2035, and the power sector is fundamental to the energy outlook, within it coal still emerges as the fuel of choice. There is also a trend that a reduced surplus of natural gas and coal for export is increasingly diverted to domestic market. The growing energy demand in most developing countries, particularly in ASEAN region, consequently leads to the need to develop the best strategy in utilising the available energy sources to maintain sustainable development (Abdullah, 2005).

National Energy Policy, as stated in the Government Regulation of Republic of Indonesia No. 79/2014, states that the amounts of fuels production from various sources are as follows: (1) Renewable energy is minimum 23 %; (2) Oil is less than 25 %; (3) Coal is minimum 25 %; and (4) Natural gas is minimum 22 %. This indicates that coal and renewable energy, including biomass, are still very important fuel sources to produce energy. The increasing demand for energy should also be accompanied by clean technology for clean environment. The development of clean coal technology that leads to environmentally friendly and yet economical coal technology can be achieved by improvement in combustion efficiency, reduction in investment and operation cost, reduction in emission of gaseous and particulate pollutants, and utilisation of combustion by-product (Sasongko, 2007).

Higher education has a critical role in creating a sustainable future. Higher education institutions have a responsibility to increase the awareness, knowledge, skills, and value needed to create a just and sustainable future (Cortese, 2003). The challenges of chemical engineering education include equipping graduates with the essential attributes for the professional chemical engineer as well as challenging the intellectual of

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students (Wood, 2003). Considering coal as a fossil-based fuel that has negative perception of not being environmentally friendly, teaching these topics to students must be accompanied by more insight and awareness on developing clean coal technology from environment and economic point of view. Chemical Engineering Program ITB is ABET accredited program and aims to address this issue by teaching undergraduate students a course that give the students an insight of the processing and technology of fuel, in particular, coal-based fuel, through course Chemistry and Technology of Coal. This paper reports an analysis of the course that has been delivered to the students in the last three years and gives best practice and knowledge sharing.

2. Overview of Chemistry and Technology Coal Course

Coal Processing Technology Course (3 credits) has been delivered to Chemical Engineering students since the beginning of 2000s. It served as an elective course with the name Coal Processing Technology (TK5007), intended for fourth year (senior year) undergraduates and graduate students. Since the implementation of 2013 Curriculum for Chemical Engineering, the course was split into Chemistry and Technology of Coal (TK4027), intended for undergraduate students, and Coal Processing Technology (TK5007), intended for graduate students. The 2013 Curriculum for Chemical Engineering with option Chemical Technology in Semester 5 comprises of 6 credits of elective courses. Among other courses, TK4027 course has been a favourite for junior students to enrol, with participant each semester comprises of approximately sixty students.

Table 1: Related student outcomes and performance indicators for Course TK4027

Student Outcome	Performance Indicators
(a) an ability to apply knowledge of mathematics, science, and engineering	(a.1) combine mathematical and/or scientific principles to formulate models of chemical, physical, and/or biological processes and systems relevant to chemical engineering
(c) an ability to design a system, component, or process to meet desired needs with realistic constraints	(c.1) analyse and synthesise chemical engineering unit operations, including integrated complex systems consisting of multiple unit operations (c.2) analyse and synthesise constraints such as economic, health and safety, ethical, environmental, and social considerations in designing systems and processes
(g) an ability to communicate effectively	(g.1) produce effective written communication (g.2) produce effective oral communication (g.3) adapt their presentation style and content to match the audience
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context	(h.1) awareness on global economic, environmental, demographic and political issues (h.2) awareness of the impact of engineering decisions on the local and global environment, economy, and society
(i) life-long learning: a recognition of the need for and an ability to engage in life-long learning	(I.1) be proficient in the use of a variety of informational and educational media i.e. traditional textbooks, journals (I.4) have the ability to learn on their own

The learning objective of Chemistry and Technology of Coal (TK4027) Course is to introduce students on coal processing and technology of coal. The Course Learning Outcomes are as follows: After enrolling this course, students are expected to be able to:

1. Have an understanding regarding coal terminologies and properties, utilisation and processing
2. Have an understanding regarding the development of coal processing technologies that leads to environmentally friendly and clean technologies
3. To synthesise a simple design on coal utilisation

Correlating to ABET Classifications based on ABET Engineering Criteria (Felder & Brent 2003), the specific Student Outcomes that expected to be attained in this course, following with the performance indicators, are listed in Table 1.

The main reference books for this course are: (1) Chemistry and Technology of Coal (Speight, 2013), and (2) Clean Coal Engineering Technology (Miller, 2011). The topics are as follows:

- Terminology and classification: definition of fossil fuels, coal, and classification based on standards e.g. ASTM, ISO, British, lignite, subbituminous, bituminous, anthracite.
- Geology and resources: coalification, world and national resources, reserves and production.
- Recovery and preparation: mining technology, preparation for utilisation and further processing.

- Properties: proximate analysis, ultimate analysis, calorific value, petrography analysis, reactivity.
- Thermal decomposition: principles of thermal decomposition during coal processing.
- Carbonisation: principles of carbonisation, operating conditions, carbonisation technology.
- Combustion: principles of combustion, operating conditions, direct and indirect combustion, coal combustion technology.
- Gasification: principles of gasification, operating conditions, gasification media, gasification technology including underground gasification.
- Liquefaction: principles of liquefaction, direct and indirect liquefaction, operating conditions, liquefaction technology.
- Clean coal technologies: development of clean coal technology to reduce environmental impact, utilisation of coal combustion residues, utilisation of biomass waste for co-firing and co-gasification, CO_2 capture and storage.

3. Teaching Strategies

The perspective of clean coal technology was emphasised in the lecture since the beginning of the class, based on the keynote speech on Development of Clean Coal Technology (Sasongko, 2007). It is hoped that since the first lecture, students will have awareness on coal that is not a “dirty” fuel, but there are many ways to develop clean coal technologies that may utilise coal as the fuel source but also will have a low environmental impact. Table 2 shows a typical course minute of lectures in each week that follows the syllabus in 2013 Curriculum. The lectures were delivered every week, and at week 8 and 16, mid-semester and final examination were held. At the middle of semester, students were prepared to propose a topic for student paper. Each student, with timeline of 5 - 6 week, synthesised the paper. The assessment components include examination scores, quizzes, quality of student paper and their presentations.

Table 2: Typical TK4027 minutes of lecture

Weeks	Topics	Learning Method
1	Introduction	Lecture, Discussion
2	Coal Utilisation in general, Biomass Torrefaction	Lecture, Discussion
3	Coal Classification	Lecture, Quiz
4	Presentations: Resources and Reserves	Student Presentation, Discussion
5	Thermal Decompositions	Lecture, Discussion,
6	Coal Properties and Coal Reactivity	Lecture, Discussion, Tutorial
7	Coal Combustion, student Paper topics	Lecture, Discussion,
8	Mid Semester Exam	
9	Gasification	Lecture, Discussion,
10	Liquefaction	Lecture, Discussion,
11	Discussion of Student Paper topics	Interactive discussions
12	Clean Coal Technology	Lecture, discussion
13 - 15	Student Presentations and Discussions	Presentation
16	Final Exam	Presentation

The general teaching strategies are lectures in class and followed by discussions. In some topics, usually at the middle of semester, a number of students were asked to prepare a presentation regarding a specific topic, for example, regarding Coal Resources and Reverses, or Thermal Decomposition. The students then gave a presentation, and by the guidance of lecturers, a discussion session was initiated. This helps students to have initiative to ask questions, and help students answer the question, while still obtained more comprehensive explanation from the lecturers. Usually the student has a vague answer, which necessitates a proper explanation from the lecturers. In addition to lecturers, the role of assistant is crucial to guide the session.

Another way of teaching strategies is to give a video regarding plant in practice. As an example, a video regarding engineering works of Paiton power plant in East Java was shown to the students. Then the students were explained about the correlating equipment and how the plant utilised a system to reduce the SOx prior to releasing the off gas to the atmosphere. By combining other learning experiences such as presentation from industry or internship student with video description, the students can have more descriptions regarding the systems and equipment that applied for clean coal technology.

3.1 Student Outcome Analysis

After the course is finished, the lectures conducted a course assessment. This is crucial in the ABET-accredited program, as the philosophy of ABET is to conduct continuous improvement. The recommendation from previous year was added and implemented in the current year for better quality improvement and commitment.

Figure 1 shows the results of Student Outcome assessment for year 2014/2015 and 2015/2016. The horizontal axis shows the performance indicator related to the student outcome, while the vertical axis shows the percentage of attainment for the students that have score more than 75 %. For performance indicator a.1 (ability to combine mathematical/scientific principles) in year 2014/2015, an exam question related to calculating proximate analysis of coal in different bases was chosen, and the level attainment is 93 %. This is understandable as exam question assessed was in the level understand / Cognitive level 2. In 2015/2016, the exam problem chosen was to interpret the swelling phenomena of thermal decomposition of coal (Cognitive level 3 – apply). The level attainment is 79 %.

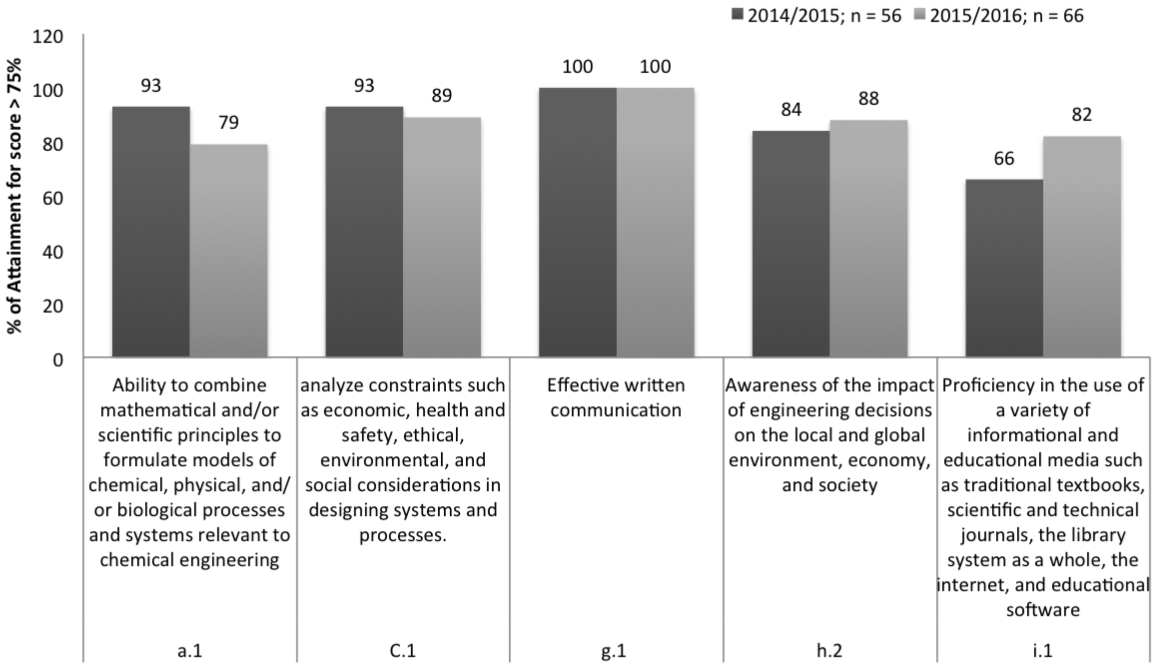

Figure 1: The Attainment of Student Outcome in Course TK4027 Year 2014/2015 and 2015/2016

Regarding Student Outcome (c) ability to design, the problem assessed in 2014/2015 was to explain and sketch Fluidised Bed Combustion Technology, correlating to Cognitive level 3. The level attainment of students who has a score more that 75 % is 93 %. This is relatively similar to 2015/2016, whereas the level attainment is 89 %. The attainment of Student Outcome (g) is relatively constant, with 84 % at 2014/2015 and 88 % at 2015/2016. The assessment of ability to communicate effectively (Student Outcome (g)) is represented by a rubric on scientific writing. It shows that all students are able to write effectively, noted by the 100 % level attainment, while the assessment of Student Outcome (i) (Lifelong learning) is measured from the ability of the students to rewrite their paper abstract. The level attainment increases from 66 % in 2014/2015 to 82 % in 2015/2016. It is expected that this attainment will be kept on 80 %. Overall, the course assessment shows good achievements of students in junior year in understanding the course.

3.2 Student Paper and Presentation

The topics of student paper are not only limited to coal utilisation, but also to the related topics, for example the utilisation of coal-based wastes, such as fly ash and bottom ash. The rubrics for Student Paper Evaluations are the following: (1) Is research question has been stated in the paper? (2) Are the references represent literature review? (3) Is the literatures have been critically analysed, or for simulation, are the assumptions relevant? (4) The use of scientific writing and language (5) Paper format comply the requirement.

Figure 2 shows the number of student paper topics from 2013/2014 to 2014/2015. The majority trends of the topics are gasification (including the co-gasification of coal with biomass), liquefaction, and combustion. Coal gasification and liquefaction are the major advanced and recent technologies that convert coal into more economical products. Gasification can result into coal-based chemicals, such as methanol, ethanol, dimethyl ether, and liquid fuel via Fischer-Tropsch; while liquefaction also increases the value-added coal into liquid fuels i.e. gasoline and diesel . There is a significant increase in the topics of fly ash, from 1 paper to 9 papers in year 2015/2016. This shows the awareness of students to utilise fly ash, a coal waste, into an economical product, such as adsorbent, zeolite, and concrete. Some of the student papers that studied modelling of coal processing using ASPEN Plus and ASPEN HYSYS have been processed further and presented in an international conference. The students are also allowed to use their papers for paper competitions and student presentation in national and international conference, for example Prasetyo et al. (2014) and Luthan et al. (2014). This encourage students to write better paper and as an exercise focusing to Student Outcome (i) life-long learning.

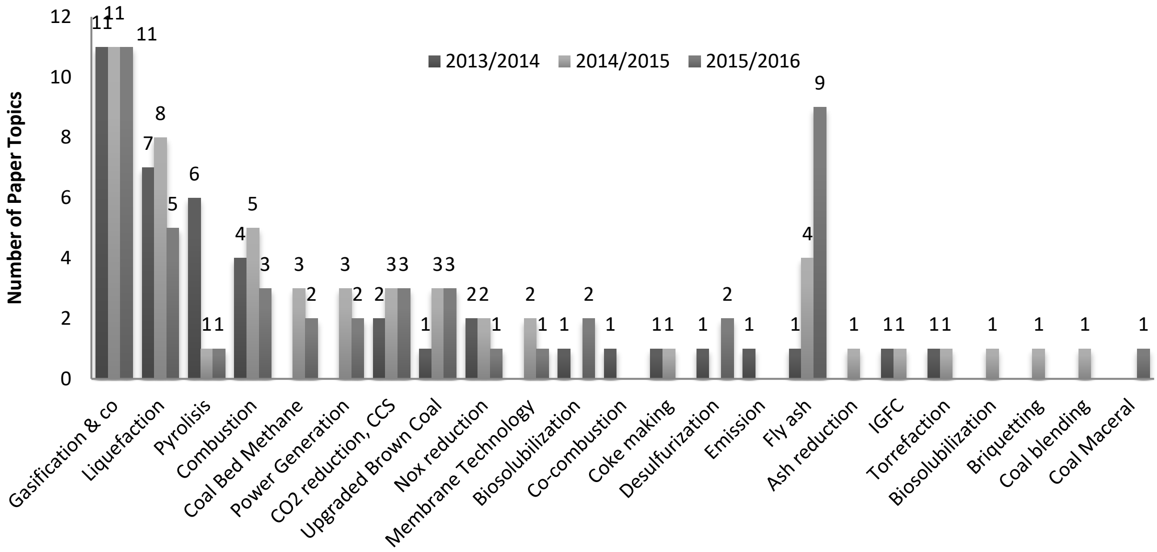

Figure 2: Student Paper Topics for Year 2013/2014, 2014/2015, and 2015/2016

3.3 Student Feedbacks and Lesson Learned

The response from the students at the end of semester regarding the feedback of learning and teaching TK4027 is shown in Figure 3. The score ranges from one to four; one is unsatisfactory while four is very satisfactory. The overall response from the students regarding this course has been satisfactory. The students' perception of lecturer capability on delivering the course is more than satisfactory, with score more than 3.5. The benefits for students have been perceived as satisfactory, suggesting that the area for improvements are still available. The student understanding has increased from satisfactory to more than satisfactory. Based on the course assessment and student feedback, the action plan that need to be made are adding tutorials and more practice with course assistant prior to mid-semester examination and final examination, inviting guest lectures from industry or research centre to give more description to students regarding specific topics, and keep adding videos as learning experience for students to see the real industrial equipment and technology. The guidance for writing student papers also should be maintained while increasing the quality of guidance to produce a good quality student papers, and give students enough knowledge, skills, and awareness on the application of clean coal technology, especially for national or regional area.

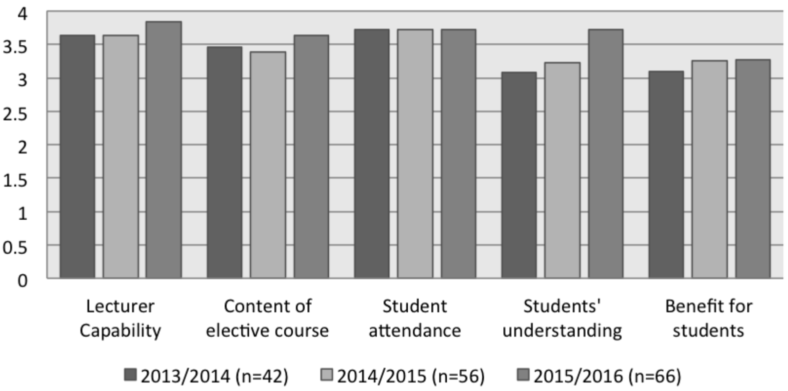

Figure 3: Student Feedback on Chemistry and Technology of Coal Course

4. Conclusions

The description and knowledge sharing of learning and teaching Chemistry and Technology of Coal as elective course for Chemical Engineering students in the junior year have been presented in this paper. By conducting ABET Student Outcome analysis at the end of semester, the course can be evaluated for further continuous improvement in the following year. By assigning students to synthesise student paper regarding coal technology topics, the students have awareness on the development of clean coal technology, while by presenting in front students give more broad knowledge on coal processing, for example, in the topics of gasification, liquefaction of coal, coal combustion, and utilisation of waste. The feedback from the chemical engineering students at the end of the semester suggests that this course is helpful for them to have good basis knowledge about coal processing, but still there is a lot of room for improvement for better learning and teaching this area.

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