DEVELOPMENT OF INDUSTRY-ORIENTED MASTER DEGREE PROGRAM IN MECHANICAL ENGINEERING AT INSTITUT TEKNOLOGI BANDUNG: LESSONS LEARNED

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Abstract

*The Mechanical Engineering Department at Institut Teknologi Bandung (ITB) was established in 1941 during the Dutch colonial rule as the first mechanical engineering program in Indonesia. The Master's Degree program in mechanical engineering was added to the Study Program much later in 1987. Both programs (*Sarjana *and Master's Degree Programs) have been awarded an 'A' grade from the Indonesian National Accreditation Board/*Badan Akreditasi Nasional (BAN).

However, over the years participation in the Master's Degree program has been low, with an average of less than 20 students per year. The stringent application requirements to enter the program and the lucrative salary packages offered by the industries might be the most common reasons why people refrain from pursuing a Master's Degree that requires them to spend a 1.5 to 3 years of study time.

Since 2008, two new approaches have been introduced into the Master's Degree program. First, the Fasttrack Program, which allows high-achieving students to accomplish both the Sarjana *and Master's Degree programs in 5 years. The other is called Credit Earning Activity (CEA), which allows industrial employees to attend the Master's Degree program without having to retire or take a leave from their work.*

This paper discusses the experiences and lessons learned from 25 years of administering the Master's Degree Program in Mechanical Engineering at ITB. Several efforts have been made to improve the quality of the program.

Keywords: *Mechanical Engineering, Master's Degree Program, Fasttrack Program, Credit Earning Activity (CEA), The Three-Lane Profession Grading (P3JJ), Engineers*

1. Introduction

The history of mechanical engineering in Indonesia cannot be separated from the history of the Dutch colonialism. It began with the establishment of Technische Hogeschool te Bandoeng (TH Bandoeng) on July 3, 1920 as the first higher education engineering school in Indonesia. The Mechanical Engineering Department was established later on August 1, 1941 as part of TH Bandoeng. During World War II (1942-1945), TH Bandoeng was renamed Bandung Kogyo Daigaku and in 1946 it was annexed as The Faculty of Engineering of the University of Indonesia. In 1957 the Mechanical Engineering Department produced its first graduates. Finally, on March 2, 1957, this school was inaugurated as Institut Teknologi Bandung (ITB). In its early days, the curriculum of the program was designed to be accomplished in 5 years. However, in 1973, the study time was gradually reduced into 4 years.

The Master's Degree Program in Mechanical Engineering began in 1987. Its initial aim was to provide its graduates with the knowledge and skills that would enable them to develop careers as operation, design, and development engineers, or as researchers, and faculty members, should they be interested in pursuing a Doctoral Degree. The Master's Degree Program in Mechanical Engineering also provides its students with materials that prepare them to meet the requirements for any professional engineer certification. The program covers a wide spectrum that enables prospective students to choose a particular field of study that suits their needs [1].

Both the Sarjana (Undergraduate) and Master's Degree Programs have been awarded A-level accreditation by the Indonesian National Accreditation Board (BAN), which is to be reassessed every five years by the same body.

2. The Curriculum of The Master's Degree Program in Mechanical Engineering ITB

Admission Requirements

In order to be admitted to the Master's Degree Program in Mechanical Engineering, candidates must have a minimum undergraduate GPA of 2.75 out of a maximum of 4.00 and a minimum GRE score of 475 (GRE is the standard admission test of the Master's Degree Program). As an additional requirement, candidates must have a minimum TOEFL (*Test of English as Foreign Language*) score of 475.

Registration and Admission Test

The academic calendar starts in August every year. Registration and admission test are administered in May before classes start. Candidates can also register themselves in the middle of every academic year, during the Even Semester, which starts at the end of January. Admission test schedule and place will be informed by facsimile, mail, telephone, or email to candidates who have met registration requirements.

Curriculum Structure

Before earning a Master's Degree in Mechanical Engineering, students must take 36 credit hours of taught courses (Master's Degree by course) or research (Master's Degree by research). Students are allowed to take a maximum of 12 credit hours per semester. Thus, the whole study can be accomplished in 3 semesters, and maximally in 6 semesters.

Fields of Concentration

The Master's Degree Program in Mechanical Engineering covers a wide spectrum of fields of concentration which allows students to choose a program most suitable to their needs. Nine fields of concentrations are offered:

1. Thermo-fluid Engineering
2. Power Engineering
3. Engineering Design
4. Dynamics and Control
5. Predictive Maintenance
6. Material Engineering and Processing
7. Failure Analysis and Engineering Life Assessment
8. Manufacturing Processes
9. Automation and Manufacturing System

Every year, not more than 20 students are accepted and the number keeps on decreasing. The main reason for this is that upon completing their undergraduate study, most graduates choose to directly seek lucrative employment opportunities in the industrial world rather than pursuing a Master's Degree, which would necessitate them to spend another 1.5 to 3 years of study time. In addition, most industrial companies in Indonesia tend to treat applicants with or without a Master's Degree in the same manner, thus undervaluing Master's Degree holders. Another reason is that there have been a significantly increasing number of scholarships offered by overseas universities and this seems to be more attractive to those who wish to pursue further studies abroad.

Fasttrack Program

Since the introduction of the 2008 curriculum, the Mechanical Engineering Department has been offering opportunities for high-achieving Sarjana Program students to directly continue their education to the Master's Degree Program, thus enabling them to accomplish both levels within only 5 years. Under this Fasttrack Program, final-year Sarjana Program students are permitted to take a minimum of 9 credit hours of Master's Degree Program courses. In the following year, upon completing their Sarjana Program, fasttrack students are automatically registered as Master's Degree Program students and must continue to take the rest 27 credit hours including thesis writing. Each year, 8 students in average enrol in this program, which entitles them to a free tuition fee voucher. The program has been adopted by some other departments at ITB.

The impacts of the fast-moving industrial world have also reached the service industries. One of the most obvious effects is the growing needs for high-quality employees who possess technical, practical, and professional skills to handle the operation and development of industrial equipment in delivering services to the customers.

Various educational as well as training programs have been created to meet the increasing demands above. However, such educational and training programs are mostly scheduled separately from that of the main working activities, affecting the availability of staff to run operations in the industries.

Moreover, in order to attend the Master's Degree Program in Mechanical Engineering, an employee must take a 1.5-year leave of absence from work. Hence, a company would lose a worker during the period. Should this occur, it would take some time for the company to recruit a new employee who needs an adaptation to the working environment, which is disadvantageous to the company's performance.

In most higher education institutions, more focus is given to technical or engineering programs that prepare the students to become future researchers and engineers. Yet, another challenge for these institutions is to develop an education program in engineering that meets the industrial demands and the needs for technological innovations. What a modern working environment needs nowadays is an education program in mechanical engineering that incorporates inter-disciplinary fields of knowledge such as management, leadership, and entrepreneurship into its curriculum.

In order to bridge the gap between the current state of the master's level education in mechanical engineering and the needs of the industrial world, several national as well as overseas universities have collaborated with the industries to develop practice-oriented educational programs [2-4]. Education and training for industrial workers are keys to future economic growth. Investments in education and training are as important as investments in research and development [5].

The following are some features that such a program must offer:

- students do not have to conduct an independent research;
- the materials prepare them to meet the market demands;
- students can learn not only technical but also managerial skills;
- researches and practical work are conducted in the industries from which students come or in the relevant fields of industries.

3. Master's Degree Program with CEA Scheme

Industrial companies generally have their own human resources development programs that provide gradual education to their employees. Usually they offer training programs of which durations range from 1 week to 1 month. Companies cannot possibly afford long-term education programs as they might lose workers for a long period of time whereas they are always in need of highly skilful workers to keep the wheels running. It is because of these reasons that time-consuming degree programs are not an interesting choice.

The Mechanical Engineering Department of ITB has developed a Master's Degree Program that is run not on a continuous basis but in terms of training modules. A training module, which is equal to one single course, is conducted in 4 weeks. In the first week, participants attend taught classes. In the second week they return to their work. Another series of taught classes are given in the third week. Thus, a module is finished in 80 to 90 hours. A module may also require the students to do some homework, assignments, and a final examination. When assignments are required, students are to submit them at the end of the fourth week. The learning process starts with a lecture in the morning and tutorial at noon. Upon completing a module, a student will receive a certificate as a token for the number of credits earned. The grade awarded is valid for a period of 5 years. When a grade expires, one must sign in for a re-test. The module scheme is shown in Fig. 1. This scheme is called Credit Earning Activity (CEA). To follow a CEA module, participants do not have to be registered as Master's Degree Program students.

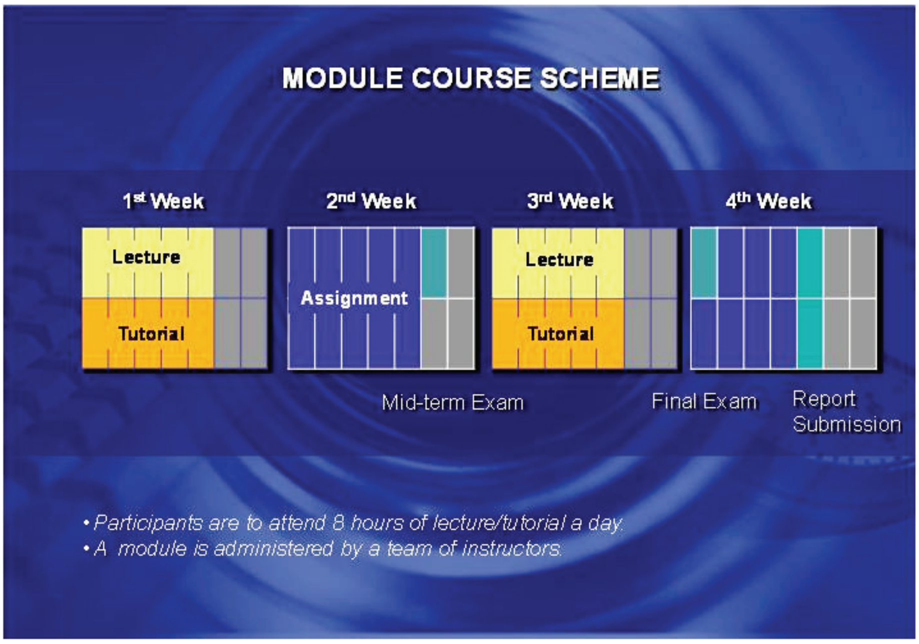

Fig. 1. Module Course Scheme

Companies may wish for a series of modules to be organized in a continuous sequence. After completing several modules, participants can register themselves at the Master's Degree Program at ITB. The maximum number of CEA credit hours that the Institute can acknowledge is 12. After being admitted to the Master's Degree Program, students can continue their study by taking other CEA modules or attending regular courses to a total of 24 credit hours. For, to earn a Master's Degree in Mechanical Engineering they must take minimally 36 credit hours. Fig. 2 shows the scenario for attaining a CEA-based Master's Degree.

The Mechanical Engineering Department of ITB launched its first CEA program in collaboration with a state-owned power company. The company employs about 3,000 engineers of various fields of expertise to operate and maintain its 9,000 MW plant. Reliable, skilled engineers are indeed needed to maintain smooth operation of the plant and provide constant power supply, particularly for Java and Bali areas.

As part of its human resources policy, the company adopts the Three-Lane Human Resources Grading (P3JJ). Applied as a general career development design for the employees, P3JJ specifies a set of expertise standards for different types of work in the company [6].

The Three-Lane Profession Grading (P3JJ) [7]

The Three-Lane Profession Grading is adopted to define and construe parameters of human resources skills and to use them so that employee's skills match their work placement. There are relations between diverse lines or fields of business, work, expertise, skills, or profession. While fields/trees of businesses are generally classified based on the types of products or services produced, fields/trees of work are classified into the types of technology or processes involved. As for fields/trees of profession, the classification is generally based on the levels of learning or difficulties that employees undergo. Organizational and economic factors, for example, can change a business tree. Similarly, a work tree is affected by technological aspects and a profession tree by learning aspects. In Fig. 3, a profession tree is shown to have three equal lanes.

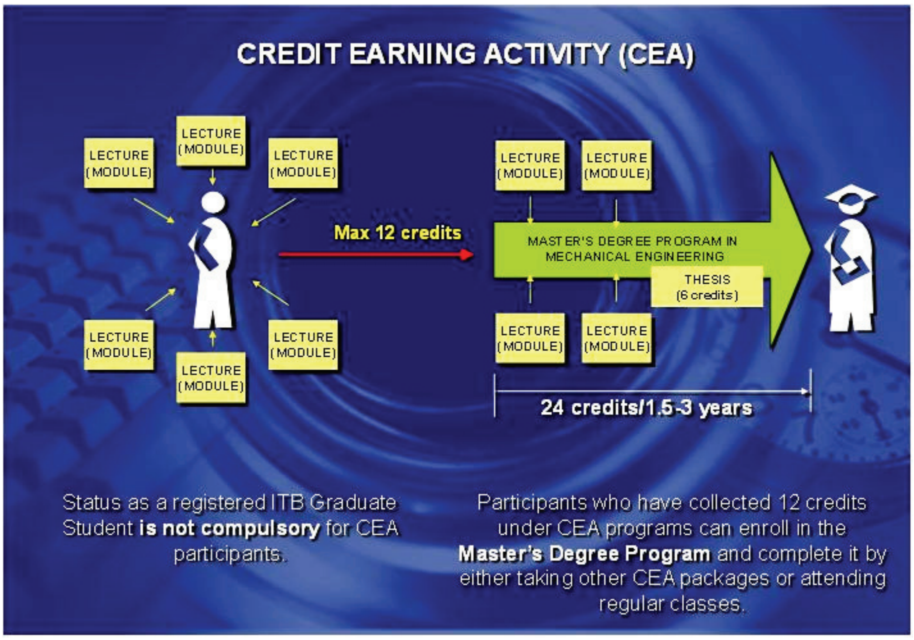

Fig. 2. CEA Scheme

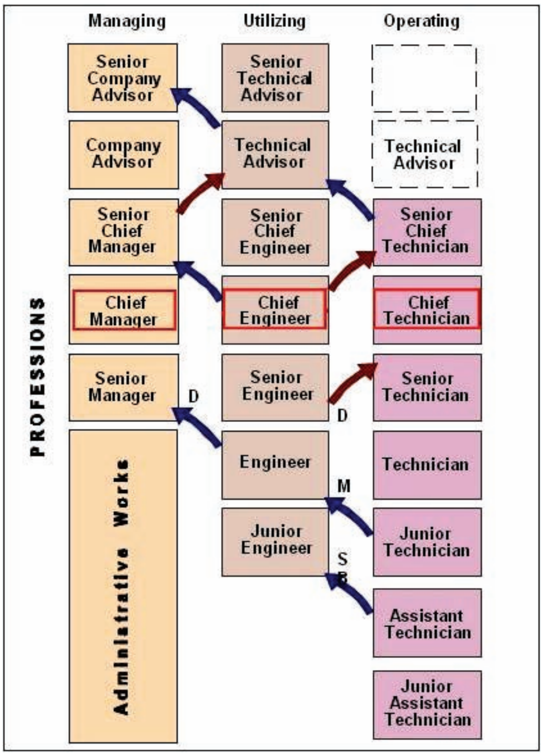

Fig. 3. Profession tree based on three-lane grading (P3JJ) [7]

1. Operating Lane: this lane puts an emphasis on machinery/equipment/method/program operation, while highlighting skill aspects.
2. Utilizing Lane: this lane puts an emphasis on the utilization of main as well as supporting facilities, while highlighting analytical aspects.

3. Managing Lane: this lane puts an emphasis on work management, while highlighting aspects of work accomplishment coordination.

Fig. 3 shows that in the Utilizing Lane an employee's career improves along with the learning process as well as the work volume and level of difficulty that he/she experiences. Therefore, engineers who are employed in this lane must undergo a process of learning that is suitable to the career development possible in this lane. This can be achieved through the CEA scheme.

After in-depth sessions of discussions with the Director of Human Resources and the General Manager of Power Plant Unit to identify the needs for competence among the mechanical engineers employed in the Utilizing Lane, a new Master's Degree Program Curriculum with a CEA Scheme was then prepared for mechanical engineers working in the Utilizing Lane of the power company (Fig. 4). This CEA scheme is a good choice for engineers to prepare them for any work or position they are assigned to.

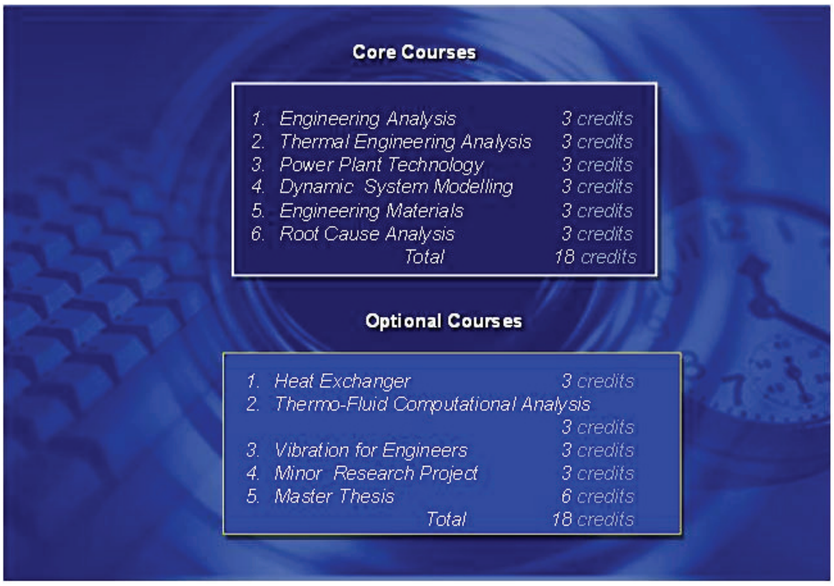

Fig. 4. Power Plant CEA Master's Degree Program Curriculum

Every module in the curriculum has its own syllabus, materials, and schedule. Tab. 1 through 3 show respectively the syllabus, materials and schedule for the Thermo-fluid Computational Analysis Module.

The CEA-based Master's Degree Program for the power company started in 2007. Generally, three modules are conducted every year. The number of modules conducted is contingent upon the company's or the employees' business and work activities. Some of the employees who had participated in the CEA modules above were given an opportunity to attend the Master's Degree Program at ITB.

In early 2009 (even semester of the 2008-2009 academic year), the participants of CEA modules applied to ITB's Master's Degree Program in Mechanical Engineering. Out of 25 (twenty-five) applicants, 22 (twenty-two) met the requirements. After admission into the Master's Degree Program, they continued with the other CEA modules, except for thesis writing. Thesis is written under the supervision of 1 or 2 supervisors and consultation schedule is subject to agreement between the supervisor(s) and the student. Until the time when this paper was written, 7 (seven) employees had graduated. In a very short time, some other employees will finish their theses.

The following comments should be noted regarding the CEA Program that has been conducted in collaboration with the above power company:

- all participants were able to follow the modules seriously. However, results of tests, exams, homework, and assignments indicate that not all participants were able to obtain a 'B' or higher grade,

- participants generally chose work-related cases as topics of their theses. This is beneficial for them as their theses can help them solve their work problems in a scientific way,
- a minor research course might help students prepare their research topics for their theses,
- most of the students of the Master's Degree Program in Mechanical Engineering were core employees of the company. They were the backbone of the company's power plant operation and maintenance. Consequently, they frequently had to prioritize their work problems in the company over the opportunity and time to write their theses.

4. Conclusion

This paper presents the lessons that the Master's Degree Program at ITB have learned from its 25 years of experience. The lessons can be summarized as follows.

- Participants of the Master's Degree Program in Mechanical Engineering come from higher education institutions, research institutes, and the industries. However, the number of candidates that can be admitted has been small. Long study time and preference to choose lucrative jobs in the industries are among the causes of the low participatory level. On the one hand there are actually many employees who wish to take the program. They would have to leave their work for quite some time to do this and generally, companies object to the idea of their employees being full-time Master's Program students.
- Industries have their own human resources development programs. Employees are given gradual educational programs. Therefore, engineers must undergo a process of learning that is suitable to the career path they wish to take. CEA scheme is a learning gateway that employees can choose. Employees who have accomplished a number of CEA modules have the opportunity to enrol in ITB's Master's Degree Program in Mechanical Engineering without having to leave their work for a long time.
- The Master's Degree Program allows them to deepen their knowledge, expand their experience, and conduct a research that may be useful to the industries in which they work.
- Thesis writing is one of the main problems that CEA-based Master's Program students still face. The program is seeking a solution to minimize or even eliminate the problem.
- Similar CEA-based Master's Degree Programs will be offered and applied to other industries or institutions.

References

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Tab. 1. Module Syllabus: Thermo-fluid Computational Analysis

<table>
<tr><td>Code:
CEA5041</td><td>Credit:
3</td><td>Semester: -</td><td colspan="2">Research Group:
Energy Conversion</td><td>Status:
Optional</td></tr>
<tr><td colspan="2">Activity</td><td colspan="4">Lecture</td></tr>
<tr><td colspan="2">Course Title</td><td colspan="4">Thermo-Fluid Computational Analysis</td></tr>
<tr><td colspan="2">Short Description</td><td colspan="4">This module covers basic principles of numerical method implementation for analyzing fluid flow and heat transfer. Several numerical analysis methods for solving fluid flow and heat transfer problems, such as finite difference, finite volume, and Monte Carlo technique, are discussed in this module. Several widely used commercial software packages, such as Fluent® and Cycle Tempo®, are introduced in this module so that participants can have a direct experience in utilizing such software.</td></tr>
<tr><td colspan="2">Goals</td><td colspan="4">After completing this module, participants are expected to:
1. Understand the basic principles of the numerical method in fluid flow and/or heat transfer;
2. Be able to operate commonly used computers and software packages (such as MS Excel and Freemat/Matlab) to solve simple thermo-fluid (fluid flow and/or heat transfer) problems;
3. Share their experience in using commercial/professional computers to solve thermo-fluid problems.</td></tr>
<tr><td colspan="2">Instructors</td><td colspan="3">1. Nathanael P. Tandian (NPT)
2. Hendi Riyanto (HR)</td><td>3. Abdurrachim Halim (AH)
4. I Made Astina (IMA)</td></tr>
<tr><td colspan="2" rowspan="2">Activities (hours/day)</td><td>Course</td><td>4</td><td></td><td></td></tr>
<tr><td>Tutorial</td><td>4</td><td></td><td></td></tr>
<tr><td colspan="2" rowspan="3">Assessment</td><td>In-class assignments</td><td>25%</td><td colspan="2"></td></tr>
<tr><td>Midterm Exam</td><td>35%</td><td colspan="2"></td></tr>
<tr><td>Final Exam</td><td>40%</td><td colspan="2"></td></tr>
<tr><td colspan="2" rowspan="3">References/Bibliography</td><td colspan="4">S. V. Patankar, Computational of Conduction and Duct Flow Heat Transfer, Innovative Research, Inc., Mapple Groove MN, USA, 1991</td></tr>
<tr><td colspan="4">S. V. Patankar, Numerical Heat Transfer and Fluid Flow, Hemisphere Publishing Corp., Washington, USA, 1980</td></tr>
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</table>

Tab. 2. Thermo-fluid Computational Analysis Module Materials

I.	**INTRODUCTION**	2.	Ray Tracing
1.	Experimental vs. Analytical/Modeling Approaches	3.	Radiation Heat Transfer Formulation
2.	Numerical Method Approach: Finite Element, Finite Difference Methods (including Finite Volume Method)	**IV.**	**FLUENT 6.3 PROGRAM PACKAGE**
3.	Essential Equations in Thermo-fluid Analysis: Fourier's Equation, Newton's Cooling Equation, Energy Equation, Momentum Equation (Navier-Stokes Equation), etc.	1.	General Overview of Fluent Package + Gambit
II.	**ANALYSIS WITH FINITE DIFFERENCE/FINITE VOLUME METHOD**	2.	Pre-processing with Gambit Package
1.	General Forms of Difference Equations	3.	Main Process
2.	Discretization of Differential Equations and Main Grids	4.	Post-processing in Fluent Package
3.	Conduction Problems: Steady and Transient Conduction	5.	Calculation: Conduction, Convection, Mixture, and Reaction
4.	Grid/Mesh Construction and Its Impacts	**V.**	**CYCLE-TEMPO PROGRAM**
5.	'Source' Term Linearization	1.	General Overview of Cycle-Tempo Package
6.	Speed Field and Speed Grid Handling	2.	Application
III.	**ANALYSIS WITH THE MONTE CARLO METHOD**	**VI.**	**CASE STUDY DISCUSSION**
1.	Basic Principles and Concepts	1.	Thermal Isolator and Sharing of Experiences

Tab. 3. Course Schedule for Thermo-fluid Computational Analysis CEA Module

1st week

Time	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
07.00 - 08.00						
08.00 - 10.00	Introduction Steady State (NPT)	Transient (AH)	Grid Source (NPT)	Fluent (NPT)	Fluent (NPT)	Mid-term Exam (HR)
10.00 – 10.30	Morning Break	Morning Break	Morning Break	Morning Break	Morning Break	
10.30 - 12.00	Steady State (NPT)	Transient (AH)	Fluent and Gambit (NPT)	Fluent (NPT)	Fluent (NPT)	
12.00 - 13.00	Noon Break	Noon Break	Noon Break	Noon Break	Noon Break	
13.00 - 14.30	Tutorial (IMA)	Tutorial (IMA)	Tutorial (NPT)	Tutorial (NPT)	Tutorial (NPT)	
14.30 - 15.00	Afternoon Break	Afternoon Break	Afternoon Break	Afternoon Break	Afternoon Break	
15.00 - 16.00	Tutorial (IMA)	Tutorial (IMA)	Tutorial (NPT)	Tutorial (NPT)	Tutorial (NPT)	

3rd week

Time	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
07.00 - 08.00						
08.00 - 10.00	Monte Carlo (HR)	Cycle-Tempo (HR)	Fluent Reaction (NPT)	Tutorial (HR)	Discussion (HR)	Final Exam (HR)
10.00 - 10.30	Morning Break	Morning Break	Morning Break	Morning Break	Morning Break	
10.30 - 12.00	Monte Carlo (HR)	Cycle Tempo (HR)	Fluent Reaction (NPT)	Tutorial (HR)	Discussion (HR)	
12.00 - 13.00	Noon Break	Noon Break	Noon Break	Noon Break	Noon Break	
13.00 - 14.30	Tutorial (HR)	Tutorial (HR)	Tutorial (NPT)	Tutorial (HR)	Discussion (HR)	
14.30 - 15.00	Afternoon Break	Afternoon Break	Afternoon Break	Afternoon Break	Afternoon Break	
15.00 - 16.00	Tutorial (HR)	Tutorial (HR)	Tutorial (NPT)	Tutorial (HR)	Discussion (HR+AH)	