Integrating the Engineering Education to make it Multi-Disciplinary and Industry Oriented

Adil Naseer Khawaja
NFC Institute of Engineering and Technology, Pakistan
Corresponding Author Email: *adil_naseer@hotmail.com*

CONTEXT

The Engineering curricula designers have long been trying to integrate engineering education to impart multi-disciplinary skills and industry concepts to the engineering graduates but these efforts have generally not been successful because a complete change in thinking is required. This stagnancy in the existing engineering course has resulted in ever-increasing gap between employer expectations and engineering graduates capabilities. The old thinking style of producing single-discipline specialists must phase out and balanced-skills professionals must be immersed in the industry. If the above mentioned problem is allowed to continue, it would lead to costly interface mistakes by the fresh engineers, low productivity especially during first five years, high turnover in the organizations and loss of billions of dollars. The above argument specially applies to the oil and gas industry because this industry has multiple solutions to the same problem, which has to be optimized by collaborative team efforts and requires multiple interfaces between design teams.

PURPOSE

The below write-up proposes a “Modular Course” to be added to the undergraduate engineering curriculums, which is based on the selected applicable guidelines for all the key disciplines and ensures to produce balanced skills in the professionals imparting the ability to understand other discipline perspectives during critical design decisions.

APPROACH

In order to simulate industry project environment, the suggested modules are proposed to be taught in logical order similar to the work is performed in the industry, which includes Project Management Module, Process Engineering Module, Piping Engineering Module, Power Module and Instrumentation/Control Module.

RESULTS

The proposed course has been introduced as two weeks course in three engineering institutes for final year students and is in the process of implementation in one of them on pilot basis. The coaching sequence would mimic the real projects executed in the industry. Since Project group receives the customer requirements therefore the first Module is “Engineering Project Management”, which explains about a typical project environment, types of project contracts with implications on the project design, types of customers and project communications. Module 2, “Process” is the first technical discipline to commence project work and becomes a foundation and work-front provider for the remainder disciplines therefore becomes a critical discipline. This module explains how a vague process concept is translated into the process design, which decision options the process discipline has to face. The process group pass over the produced deliverables to “Piping” therefore the third module is “Piping”, after that the “Electrical”, and “Instrument” modules come into picture.

CONCLUSIONS

The above concepts have been applied with success in an engineering university where author teaches as Assistant Professor. The proposed modules broaden the engineering curricula to produce more practical oriented minds overcoming multi-discipline interface problem and keeping abreast with rapidly advancing state-of-art engineering industry

KEYWORDS

Modular Course, Multi-Disciplinary, Integrated, Piping, Process, Project.

Introduction

It is well established that Engineering universities are specialist at producing "single-discipline" engineers, whereas the industry requires multi-discipline professionals. The fresh engineers entering the industry know nothing about any other discipline and how to work as a team, basic understanding of technical inputs/outputs of all disciplines.

Mistakes mostly happen due to inability of one discipline to understand the information and design requirements of other disciplines and hence such mistakes are hard to correct and cause a lot of rework and wastage. Disciplines focus only on single aspect but care little about what information has to be picked up by the other disciplines, and what information has to be expedited from other disciplines.

Most of the traditional discipline engineers spend the whole project cycle in perfecting single discipline output without even thinking about the bigger picture and potential damage this attitude can cause to the overall project success. Some discipline engineers do the worse, and try to "gold-plate" one deliverable as per the customer requirements but fail to understand the impact of the decisions on scope creep and on the project as a whole.

Based on the problems stated above, below article proposes certain course modules, to be added to the curriculum of final year engineering students in the engineering universities. The rationale behind proposing this course in the final year is that these modules familiarize the students with industry standards and impart operation considerations, customer requirements, with real-time project situations, which would hopefully be fresh in the minds upon entering industry. Each module expects the students to work in a project like environment, the same way as the industry expects them to attend various problems.

Modules

Based on the real time scenarios and project situations, this course is divided into modules, which are sequenced in the same logical order as the project team works during the project execution. The modules are kept simple and easy to understand and each module would take approximately two to three days and the whole course takes around two to three weeks.

These modules help the next generation of engineers to find holistic solutions to the engineering problems and integrate the multi-disciplinary team as a single whole. All the modules are taught in a "workshop" mode, which encourages participative learning and the students are encouraged to do practical work, which is checked in the light of field experience by the instructor.

Module 1: Project Management

Module 1 is designed to explain, what is a project/job environment, what are the types of project contracts with implications to the engineers, what are the basis of the customer satisfaction and what is meant by company stakeholders influence on the technical performance of the design team, what should be the specific focus of the discipline engineers and what ideally is the role of project managers in the industry environment.

An average Customer in the today's environment, expects Contractor to perform more then what has been agreed in the contract. Also, the Customer expects the Engineering Contractor to work on numerous options, evaluate and then proceed forward. During the course of this options evaluation, project management team faces the trouble of controlling scope creep and the discipline engineers do not know how to counter-act the unjustifiable requests form the customer. Single discipline champions do not know how to make a right decision in this situation and that is why this situation leads to project delays and reworking. The project schedule and cost criteria do not change and customer pressurizes to conclude the work, with super-quality, before the contracted time, with unforeseen changes and without any additional incentive/rewards. All these challenges cannot be faced without some level preparedness.

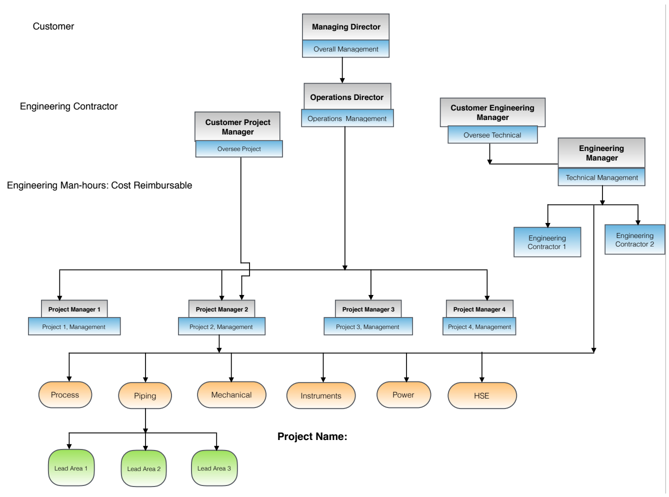

Figure 1: Typical Organizational Structure for Projects

Behavioural Model for Engineers

Even if not directly involved in the project management, the engineers should adapt to certain model and learn specific management techniques for each situation, to cater for a compromise between various stakeholders' requirements, which unfortunately are diametrically opposite to each other. Since most technical organizations undertake engineering work which entails complex efforts, performed on a fast-tracked design/implementation schedule, therefore there is a requirement of a behavioural model which could help him to develop new skills while staying effective as an engineer.

Misconceptions about Project Discipline Role:

The general notion about project group role is that project group, has unlimited powers. Some think that project group is created to punish the wrongdoers and correct all the mistakes of the project. These misconceptions create conflict in the team therefore all such concepts must be clarified to the engineers before entering any project team.

This module illustrates the above issues, keeping in view the project situations for engineering works and consists of a set of techniques, with the focus on creating awareness in shortest possible time.

Module 2: Process Discipline

Process group is the first of the technical disciplines to take in the scope requirements from project group, understand the requirements to form the "Design Basis" and then translates the Customer's requirements to basic level project schematics like "Process Flow Diagram", "Piping and Instrument Diagrams", "Cause and Effect Diagram" etc.

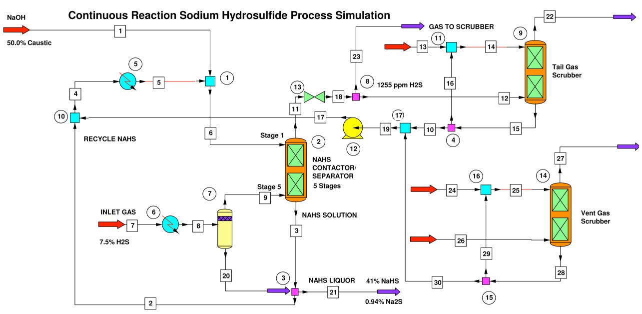

Figure 2: Typical Process Simulation

Another critical role of Process group is the responsibility to provide all the relevant information and data to the downstream disciplines, to commence with relevant project deliverables.

Music Writers for the Project team:

The term "music-writers" seems entertaining but visualizing this terminology within the tense project situation creates a paradox, yet this is the right word to describe the critical foundation role of process discipline. Limited manpower, excessive workload of producing documents to mobilize downstream disciplines, limited information from customer and too many options study, puts the process group in pressure especially during initial stages. The solution is to educate all the team how the process group functions and if required some of them should help the process group, to relieve the process group from the "load spike"

Process Discipline Troubles:

Limited resources are allocated to the process discipline, to keep the project manpower curve smooth. Process group has to work to the customer required quality, within time, with limited resources and with the pressure of the whole team (including project manager) waiting for the process flow diagrams, piping and instrument diagrams, process data sheets.

Process group has to work closely with the customer, to avoid delays and reworks, but unfortunately is often viewed as negative behaviour in-house management. Such pressures lead to various conflicts, between process group and other disciplines waiting for the "cooked" output, to proceed with work.

Module 3: Piping Discipline

Piping group has to route the pipes defined by the process group as per the project requirements, best practices and with correct material. This is not as easy as it sounds. To route one pipe may be easy but to route hundreds of pipe in the same area invites many other problems like pipe to pipe clearance, control of thermal stresses, dynamic stresses, sensitive equipment nozzles over load control, cranes, fork-lifters access where required, pipe to equipment clearance, maintainability of the equipment, accessibility of the valves and equipment and general ergonomics if the area.

Piping Importance:

Piping is the bond that holds together any industrial facility, large or small. However, because of its undramatic presence piping is often taken for granted. Piping operability, ease of maintenance, Cost and Safety are primary concerns. Piping is typically 20 to 25% of total plant cost, and 10% of all fires within the industry are related to piping. Good piping design always balances operation, maintenance, and cost. Piping is the first discipline, which brings out the design and shows it on the physical coordinates or 3D models. Proper piping design is as necessary for piping as it is for the equipment it connects. Engineering-wise, piping is the major consumer of the man-hours.

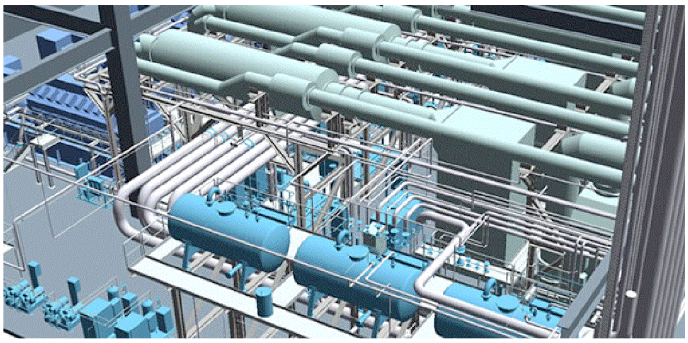

Figure 3: Typical Piping Model

Piping - Process Interface:

Piping has major interface with process group, and is perhaps most affected by the changes in the process design because every single process line change has to be captures suitably in the “Pipe Routing Diagrams”, “General Arrangement Drawings”, and “Isometrics”. Since piping group carries around thirty to forty percent of the project manpower therefore sometimes comes under pressure to produce deliverables enable project progress.

The Piping Module is a guide for the basic design and construction of piping systems. It focuses on design fundamentals, guidelines for practical installations, and specification and purchase of materials and services. It is applicable to large and small projects and covers all the oil and gas projects. These guidelines encompass the experience of the instructor in the Operating Companies. The module’s broad applicability makes it useful to both engineers and operating personnel

Module 4: Civil & Structural Discipline

Civil and Structural engineer has to deal with two main areas which include “Foundations” and “Structures”. All the designed facilities have ultimately to be rested and supported on the ground or on the structure. The equipment, which rest on the ground, has to be placed on the foundations to make the installation safe and rigid. Many “non-civil” discipline engineers do not know the difference between a shallow and deep foundation. What is the first priority foundation type i.e. shallow foundation but when can this type of foundation not be used. Another example is that all the project team must know, which is a better foundation (“combined footing” or mat foundation) keeping in view the project requirements.

If the soil has adequate bearing capacity then shallow foundations may be good enough but the problem is that in majority cases the soil is close to coastal areas or sandy soil with poor bearing capacity. In such cases the project engineer or civil engineer decide for either soil improvement or deep foundation.

Foundations and Structures:

Structural/civil Engineering deals with the analysis and design aspects required to ensure a safe, functional and economical end product. The entire exercise can be undertaken in a highly coordinated way if everyone involves understands the structural design for which it is necessary to have basic understanding of structural analysis and design.

Soil Investigations:

The topographical investigation and geotechnical studies are an important part of the Civil engineering. Normally these two are outsourced to the specialized contractors, who have to do site work (bore holes, trial pits and penetration test) and then laboratory investigation to provide critical soil design parameters. If geotechnical investigation declares that soil strength is less than required then soil improvement or piled foundation becomes the only suitable option.

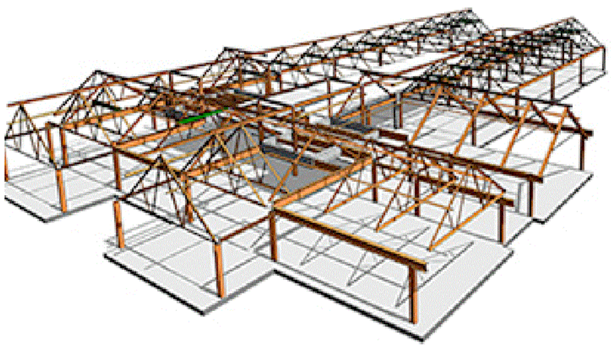

Figure 4: Structure Design

Industry Structures:

Industrial structures are required to perform a specific function, and a complete understanding of this function is critical. The selection of specific structure which may be a truss or frame depends on other important objectives (as required by site requirements, customer requirements or oil/gas industry specific requirements) that a designer should strive to meet, thus highlighting the importance of minimum basic knowledge.

Module 5: Power Engineering Discipline

Power engineering is the heart of every project and engineers know very little as compared with the importance of this key discipline. Large facilities have “Loads” distributed over a big area and placement of sub-stations and transformers can make a big difference if we talk about the cost and operations priorities. “Load List” has to be made carefully, not to over design the power source and make it costly and not to under-design it to make it difficult for any future requirements.

Figure 5: Switchgear Panels in the Substation

Power Options:

Power Module is designed to enhance the skills of the fresh engineer, by giving the details on how the power is estimated for a facility, which is the efficient way to supply this power and how it is actually provided to equipment used in the oil/gas industry. For every project, provision of requisite electrical power is either done through the national grid or is generated at site with the help of suitable generators. It necessitates the knowledge of “Sub-stations”, “Switch Gears”, “Motor Control Centers”, “Power Distribution Studies”, “Transformers” and the like.

Major Activities:

Keeping in view the above requirements, this module offers a systematic development of skills and knowledge in electrical design with the help of international standards and Codes. Without going into unnecessary details, this module starts with the power availability options (from existing HV/MV grid, from existing nearby facilities, generator option), transformer, switchgear, feeder pillar, bus bar, MCC, power distribution schemes.

Thus this module covers basic introduction to electrical design for non-electrical engineers and the course contents in this module include “Single Line Diagram”, “Sub-Station Layout”, “Fault Level Calculation”, “Cable Routing Basics”, “Distribution System Design”, “Power Factor Improvement”.

Module 6: Instrumentation & Control Discipline

Instrument & control is the nervous system of the facility and starts with estimating the Signal Inputs/Outputs, discriminating between analog and digital signals, visualizing the control architecture, working with vendor to finalize the correct protocol. Thus it is important for smooth working, safety and productivity of the facility. Instrument and Control do not decide which equipment requires which type of control, however Instrument discipline studies the process documents and then prepare instrument specifications for purchase, finalizes the control architecture diagram for the vendors and provide the required control system, prepare loop diagrams to act as supporting document for plant operations.

PLC versus DCS:

Piping and Instrument diagram and Cause & Effect chart, both of which are the output of the process discipline, are the basis for control system design. The new facility control has to be hooked up with the existing DCS system; therefore understanding of the existing system and compatibility is required. A minor change in the process scheme potentially affects the technical and commercial aspect of the control system therefore the control requirements must be fully understood by all disciplines.

This module commences with the P&IDs (supplied by the process group), signal types, I/O lists, requirement of PLC or Single Loop control, hooking up the PLC with DCS options, Discrete versus Continuous control, Protocol types, Topology of the control schemes and serial versus parallel transfer.

Conclusions

This article identifies deficiencies among engineering graduates as perceived from the existing curricula and feedback from by industry and employers. The article also highlights the importance of the multidiscipline technical education to be added to the existing engineering curriculum, to provide what is needed by the industry. These findings have clear relevance for engineering educators and employers. This study recommends six modules to overcome the engineering curriculum deficiencies and form a bridge between academics and industry.

The article stresses upon the importance of multi-discipline technical skills as a basis of engineering practice resulting in better communication, teamwork and interpersonal skills. In industry various disciplines have to be engaged in complex interactions with each other, and a lack of technical domain would obstruct in these interactions thus the integrated curriculum is an important tool for achieving project success.

As highlighted above, the teaching method of the recommended modules is workshop-based and encourages the student involvement and participation, where the students are encouraged to reflect upon previous knowledge and thus understand the concepts. This is the basic idea and is being launched in some universities including the one in which author is a faculty member. Like all the new ideas, it would need to be continuously improved, based on the feedback thus making adjustments for the subsequent course sessions.

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