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Process Engineer: Technical Benchmark, Decision Maker and Liaison Center

Ionuț UNCU
Transilvania University of Brasov, Romania, ionut.uncu@unitbv.ro

Abstract
In modern day industrial processes, lack of direction and clarity can often incur heavy losses. In order to avoid such scenarios, this paper proposes the relatively new role of process engineer (PE) within a discrete manufacturing plant to serve as a liaison center for all other activities—simultaneously functioning as a technical benchmark and a decision maker at the interface of their own area of expertise, the product development flow, the organizational chart of the plant, and the project management team. This is expected to reinforce economic sustainability and technological development in the industry. To this end, we first establish the primary requirements and responsibilities of the PE. In many organizations, the roles and responsibilities of various employees are not sufficiently well-defined, leading to ambiguous interactions between departments, large-scale inefficiency, and a significant increase in expenses. The primary tasks of the process engineer would be to help achieve industrial expectations and utilize the labor advertisement market directly or indirectly. Thus, the appointment of engineering graduates as PEs can be mutually beneficial for both the academic and industrial sectors. It would provide security of employment to fresh graduates, while their fast integration into industrial companies following graduation would secure a fast return on industrial investment.

Keywords
process engineer, teaching, graduate, student

1. Introduction

Scientists and engineers are equally important to societal progress—one discovers things that exist and the other creates things that do not yet exist. Process engineering was originally employed in Chemical Engineering but, nowadays, it is utilized in nearly all discrete manufacturing industries over the world [1, 2].

Recently, several industries have introduced roles like requirements engineer and software engineer into their architecture, highlighting the need for better structure in industrial methodology. The proposed profile of process engineer (PE) is along a similar line [3].

Definitions of positions and their integration into the framework depend on company maturity and organizational culture. However, different positions like production engineers, manufacturing engineers, industrial engineers, and process engineers share similar responsibilities. The PE is a relatively new role introduced in industrial plants to corroborate plant requirements, meet project management demands, and conduct advanced product quality planning (APQP) [4-7]. This is expected to reinforce economic sustainability and technological development of the industry.

Recently, mechanical and electronic systems have evolved a new specialization called mechatronics. Similarly, original equipment manufacturers (OEMs) wish to progress from being manufacturers to mobility providers. Similarly, the role of PE in discrete manufacturing has evolved from process engineering in continuous manufacturing to address the need for a unique professional profile to orchestrate the discipline [8, 9].

Better quality teaching at technical universities enhance the efficiency of learning in students. The courses are also required to target a high rate of employability. This needs to be accomplished through teaching curricula that combine the knowledge, skills, and attitudes required in today's labor market and society. Thus, the objectives of technical university courses must be aligned with the key performance indicators (KPIs) used in the industrial field. The outcome must be structured efficiently and be measurable. In order to ensure these output characteristics, the entire teaching process, along with all constituent factors, must be designed based on clearly defined input and process parameters [10-13].

Thus, the challenge for technical universities lies in continuously developing and improving the curricula in order to prepare graduates for future employment. The graduates should be able to find professional solutions to the complex challenges that may arise within their professional path [14].

Teaching relevant knowledge to future engineering graduates can enable the production of "super experts", who have the capability to wield a significant positive impact in both industry and society [15]. Analysis of various organizations has revealed that the role of the PE has not been outlined and structured clearly to improve efficiency and effectiveness of communication and execution. In this study, we gathered available information from the literature, industrial field specifications, and labor market advertisements to establish the state-of-the-art responsibilities of this professional industrial role [1, 16, 17]. PE is employed in various industries, including the automotive, oil, and gas industries. In all cases, it is guided by the right key performance indicators (KPIs) [18-20].

Nowadays, the term PE has come to mean a function developed in the job—in situ—which is akin to a project manager. In the future, based on the correct structural definition, better communication within the industrial field and simultaneously between the industrial field and the academic domain, the effectivity of the role can be enhanced [21-24].

In this paper, we analyze the differences between chemical and process engineering, and the limits of process, manufacturing, and industrial engineers and their commonalities. The expectations of this specialization in the industry and labor market are thereby revealed.

Currently, the requirements of a PE are not met by the capabilities of an engineering graduate. Due to the aforementioned issues and others that are outside the scope of this paper, they take up positions in random specializations, which is particularly demoralizing for them. On the other hand, teaching institutions continue to lose students every year and the deficit of well-prepared graduates in industrial companies continues [24].

2. PE in industry

The complexity of the role and function of PE has evolved over the years. It is a practically motivated position that fulfills industry demands in different fields. Unfortunately, its profile lacks clear definition, substance, or history, jeopardizing its future. In addition, students need to be trained in skills required for PE today to serve the demand for industry specialists in the future. However, the skills associated to PE are also ill-understood, complicating training at graduate and post-graduate levels. Thus, cooperation between academic and industrial sectors is critical to address this problem. This paper highlights the main ideas and standards in this topic to increase the efficiency of PE teaching and professional profile consistency from both academic and industrial perspectives. To this end, the correlations between information and data collected from industrial, academic, and market sectors are analysed [21].

Over the years, miscellaneous methodologies for process engineering have been developed by different companies. However, certain terminology used in processing require concrete definitions.

Process engineering refers to the understanding and application of principles and standards that support the transformation of raw materials and energy into finished goods within the industrial field.

Within daily workflow, process engineers design technical processes, review technical specifications of equipment, and coordinate scheduled and unscheduled calibration tests of equipment used in production lines. Instead of defining the ideal job description or an ideal portrait of a PE, the primary attributes required in this position are described in this paper. This is because the job description is dependent on factors that are plant-specific. The most common requirements of an PE includes knowledges in specific technologies (welding, laser, sensors, pneumatics, camera systems, printers, mechanical, materials and so forth) and specific tools like PFMEA, Control plan, SAP, process capability, SPC, OEE, VSM, lean six-sigma. As general responsibilities the PE ensure that any process is functioning in an efficient and cost-effective manner while complying with health and safety regulations and quality standards. In addition, the process engineer has specific responsibilities depending the job sector, defined as following:

- Monitoring the overall equipment effectiveness (OEE), including regular testing and ensuring maintenance tasks (ME) and the total productive maintenance (TPM), are carried out.
- Oversight of processes data like down time (D/T), change over (C/O), cycle time (CT) and machine time (MT).
- Supporting production personnel in the event of a problem (Problem solving, Root cause analysis).
- New product introduction (NPI) and handling of the engineering change notices (ECN) with concern for safety and quality.
- Use of statistical process control (SPC), measurement system analysis (MSA), Minitab, or other statistical tool.
- Defining the order of process steps required to manufacturing the part using bills of materials (BOM) and process flow diagrams (PFD).
- Identifying and eliminate waste along the process in order to ease manufacture and reduce cost using value stream mapping (VSM).
- Use of PDCA or DMAIC methodologies to achieve comprehensive analyses.

The roles and responsibilities of PEs have evolved from continuous manufacturing to discreet manufacturing. Therefore, process engineering is highly complex. Another topic worthy of analysis is the interference between manufacturing and process engineering responsibilities.

The difference between the roles of a PE and a manufacture engineer (ME) is attributed purely to their specializations. PEs usually specialize in chemical engineering, which gives them an advantage in designing and improving manufacturing processes. MEs are usually mechanical or industrial engineers specialized in supply chain management and operations. Their professional sites are also different. As documented in literature and verified in practice, PEs usually work within industrial plants, managing equipment such as boilers and distillation columns, while MEs work with robots, supply lines, etc. Owing to the organizational structure of modern companies, PEs end up working in manufacturing processes, leading to conflict between their responsibilities and those of MEs.

Another aspect that creates ambiguity between process responsibilities is that, sometimes, companies hire manufacturing process engineers. PEs are sometimes hired to replace MEs, introducing tool engineering or mechanics-related responsibilities into their job profile. As a result, PEs often conduct the following activities associated to assembly lines, automotive processes, etc., which brings their tasks into conflict with those assigned to production and MEs.

In this context, companies often hire PEs directly to handle processes, and limits such as manufacturing or industry are combined in one defining function. Employees responsible for managing processes are nominated as PEs. However, the types of such processes can be widely variable. In order to differentiate between them effectively, PEs in the painting industry should be referred to as coating PEs or PE in the painting domain and PEs responsible for welding processes should be called welding PEs. Such nomenclature can be generalized to other specializations.

The roles of PEs are often conflated with those of industrial engineers (IEs). IEs manage the continuous improvement of processes, systems, and organizational structures in order to improve efficiency and reduce expenses.

As in the previous case, the confusion between the two separate jobs arises from the practice of employing PEs in continuous improvement. Due to conservatism in upper management, the PE profile is not developed completely during profitable periods. In addition, resistance to change makes technical and management departments unwilling to adopt new philosophies. Instead, they choose to focus only on the present and regard the possibility of continuous improvement to be an expendable luxury. Ultimately, this is due to the lazy attitude of only embracing innovation when a competitor adopts it. Owing to their complex responsibilities, PEs interact with a wide range of primarily technical company functions on a daily basis. Tragically, in the majority of industrial companies, communication between the engineering department and other departments is very inefficient, which leads to the escalation of expenses. Process engineering comprises a wide range of responsibilities and managing multifarious technical challenges. This requires frequent collaboration with MEs over different processes. Technical knowledge is transferrable between such responsibilities, and, with time, one set of responsibilities replaces the other. Depending on the company's domain, mechanical engineering graduates could serve as PEs. This enhances their employability [2]. Graduates in mechanical engineering, mechatronics engineering, welding, oil and gas engineering, and other specializations are capable of becoming PEs. In addition, chemical engineers are often enrolled as PEs in painting sectors or workshops in industrial companies.

The roles of PEs are also distinct from those of product engineers, who are responsible for the fabrication and development of new products, the modification of existing products, designing drafts, and constructing and testing prototypes. The final design for production is issued only after all suggestions of the product engineer have been implemented. The model, diagram, materials, and other specifications of the product are distributed to all personnel involved in the enterprise resource planning (SAP ERP) system.

Process engineering follows product engineering. It is performed after new product specifications have been released for the manufacturing process. Under it, the newly released product information is developed further, the plan for production is issued, and its method of fabrication is documented. The PE prepares the equipment, fixture specifications, and work instructions, and trains the people involved in the fabrication process of the new product. Thus, PEs act as liaisons in the organization. They facilitate collaboration between product engineering teams and other support or production teams. All delays, stoppages, or queries regarding processes are referred to PEs, who analyse the issue, identify its source, and contact the relevant support team. PEs are also responsible for the identification of general tooling types required for the manufacture of new products and the approval of such tooling developed before the commencement of fabrication. This task is handled in collaboration with the purchasing, mechanical engineering, product engineering, and project management departments. Thus, the roles of PEs can vary from company to company. Routings and the bill of material (BOM) are configured into the SAP ERP system by the PE. Thus, the PE profile includes experience in tool design, tool building, plant layout, methods, time study, and other related domains. It is their job to support manufacturing processes from all perspectives, but this often sets them up for failure. Managing the fabrication of a product single-handedly is very risky. PEs are put in a position to sort, select, and decide the best overall plan. The most productive and efficient solution to this problem is to involve the experts from all the involved departments and employ a team effort [10].

PEs are indispensable to manufacturing plants. They serve multifarious roles within a wide range of manufacturing companies, such as shipyards, aeronautical companies, petrochemical companies, automotive companies, biotechnical companies, nuclear energy companies, and green energy companies. Process engineering plays a vital role during every stage of product development and production flow. During product development, process engineering manages its sustainability and cost, and PEs ensure the fulfilment of the key performance indicators (KPIs) of the plant by taking the optimal actions and decisions. The performance of PEs is continuously improving owing to new software tools that utilize simulation and analysis to identify the best decision in any situation. Before launching a detailed study of process engineering, the general position of the PE within the overall plant organization should be understood. Every manufacturing company possesses its own organizational chart. These charts clarify the working relationships between individuals from the same office, service, or department, as well as those between members of different departments. Further, if a plant is part of a multinational organization, then the working relations between the departments of different plants are also described in the organizational chart. They also indicate the general functions of various groups in the organization. These organizational charts are significantly different at every plant as they are developed to serve the company's particular interests. Further, they are revised frequently to implement and underline new changes or demands. However, despite the differences in content, the majority of organizational charts use identical templates.

Process engineering operations are consolidated into a department only in companies whose size exceed a particular threshold. Every department engineer is responsible for one or more products manufactured within the plant and following the process flow through the plant. Alternatively, they may be allocated to particular process areas (e.g., welding, fabrication, coating, screwing, gluing, etc.). In smaller companies, PEs are affiliated to different departments or teams focusing on other functions. Sometimes, even the title of PE is missing. In some cases, process engineering is performed as a part-time job by one or more engineers. However, irrespective of the existence of the title or the position, the role of PE must be fulfilled in all manufacturing companies. Thus, all discussion regarding PE or process engineering department in this study applies to any kind of processing function in any plant.

PEs develop their responsibilities with respect to the predefined KPIs' goals and objectives for the plant. These KPIs are shared among all departments for customization. The KPIs of the process engineering department vary from plant to plant, but the following are common points:

- Capacity utilization
- Overall equipment effectiveness (OEE)
- Machine downtime rate
- Machine set up time (Target: Single-minute digit exchange of die (SMED))
- First pass yield (FPY) – It's quantifying the ratio between total produced products declared as passed after first quality inspection and total amount of produced parts, the ratio been multiplied with 100. Products declared failed after quality inspection are being reworked or declared scrapped.
- Rework
- Scrap
- Training hours
- Employee turnover
- Engineering-on-time delivery - solving problem on time (no delay)
- On-time delivery
- Throughput
- Cycle time
- Changeover time
- C.I. [%] = (Number of Continuous improvement (C.I.) events closed / Total number of scheduled C.I.)×100

PEs are affiliated to project teams assigned to various projects across plants in the same group. They are responsible for supporting project development using local resources and information. Another important aspect is the role of the PE in advanced product quality planning (APQP). APQP consists of a set of procedures applied in the automotive industry to ensure that customer requirements are fulfilled during the production and delivery of products. It involves individuals from a variety of departments, motivated by the idea that compound teams from multiple disciplines can work together to develop products that satisfy customer requirements and can be manufactured with minimal cost and labour. Prospective problems are identified during the development stage, and can, thus, be addressed with minimal cost. This greatly reduces the overall lifecycle costs of developing, producing, and monitoring a product. While this increases the development costs during the initial phases, but the production and support costs are decreased, ultimately benefitting the company economically. Above all, customer's satisfaction is increased.

APQP ensures that the voice of the customer (VOC) is fully acknowledged by suppliers, and the requirements are transposed in terms of internal technical specifications and special characteristics. Product or process development is based on prevention attitudes and philosophy.

The PE's involvement becomes significant in the third phase of the product life in the APQP process flow.

The performance of PEs can be assessed based on quarterly, biannual, or yearly appraisals or self-appraisal following the successful completion of the probation period. Usually, to comply with ISO standards and internal work instructions, as well as maintain a record, the appraisal is composed on a registered and internally approved appraisal form.

The process engineering form records the agreement between the drafted performance plan and the achieved results.

The process of performance review is based on:

- Job description
- Evaluate the person's level of performance

- Go thru with each employee all the performance factors
- Offer the employee an overall rating

To analyse deeper, we need to consider the performance rating definitions:

- Performance factors
- Employee strengths and accomplishments
- Performance areas which need improvement
- Plan of action toward improved performance
- Employee comments
- Job description review section
- Signatures

The following list ranks the existing methods reported in the literature and those implemented in real-world companies in terms of effectiveness and efficiency:

1. Management by objectives (MBO) Method
   - Establishes specific, measurable, achievable, realistic, and timely (SMART) objectives
   - Uses Objectives (What) instead of Methods (How)
2. 360 Degree performance appraisal method
   - Appraisal by manager is accompanied by the anonymous appraisal by co-workers resulting in a comprehensive review [21].

3. The relationship between Academics and Industry

In order to facilitate the integration of graduates into industrial institutions, it is necessary to consider the expectations involved. Technical training in graduate courses should be optimized by encouraging learning via experimentation, sharing ideas and perceptions, executing group projects developed by students, visiting industrial companies, talking to trainers and lectors who are involved in the management or technical teams of industrial plants, reading case studies focused on problem solving and root cause analysis, developing critical thinking, conducting workshops involving employees of industrial companies and university students, etc. [22].

The professors' roles should be defined, and they should react promptly and positively to invitations from industrial fields. Initiatives are required to bring the two domains together and sculpt a mutually beneficial relationship. Such a relationship should also be sustainable over the long-term, evolving through common projects or programs to consolidate the vision of future graduates with those of the personnel involved in process engineering. The ultimate goal is to help students become familiar with industrial processes and particularities [23, 24].

The most effective method of teaching process engineering to students is by linking them directly with working environments using learning factories based on infrastructural requirements.

Academic knowledge is transferred to industrial fields through lectors, trainers (professors, lecturers, doctors, etc.), and scientific papers and presentations. This is further facilitated by the exchange of experts between academia and industry. Doctors are often recruited by companies to make knowledge transfer more effective. However, the relationship sours when they are constrained by company policy, which restricts the potential to an individual asset and prevents the company from benefitting from it. The quality of university teaching and research depends on the quality of the case studies considered, which are of practical origin. Thus, knowledge flows in both directions. If industrial companies exhibit higher willingness to provide case studies based on real processes, academic researchers will be more inclined to investigate problems highlighted by their industrial partners [25].

Now, we present the relationship between specializations achieved during academic training and the designated roles of graduates in industrial companies. Universities prepare specialized individuals who are recruited to fulfil comprehensive responsibilities within the organizational charts of companies. Teaching institutions are also responsible for setting and fulfilling sustainability and economical goals.

Over the recent years, technical education has become less popular due to popular perception. This is manifested in the empty seats in technical courses, which often result in their premature discontinuation. At the same time, the demand for process engineers is increasing, and industries of all types are looking to hire qualified and flexible technical graduates who are willing to learn.

Learning can be divided into the acquisition of knowledge, skills, and attitude. Thus, the output of all courses can be quantified in the following terms [26, 27].

- Knowledge (Cognitive domain)
- Skills (Psychomotor domain)
- Attitude (Affective domain).

Unfortunately, the current status of engineering education in universities is forcing manufacturing plants to prioritize attitude over knowledge and skills. Graduate learning has long diverged from industrial development and labor market requirements. Investment in training is vital to redress this issue. The education of young graduates in Bachelor's and Master's programs will improve the expertise of future specialists [2, 23, 28, 29].

The transfer of information is perhaps the most critical phase in process engineering. Communication of ideas can, at times, become rather complex. Product engineers communicate with PEs over e-mail, voice messages, and phone calls, but these are not sufficient. Process engineering responsibilities are also based on part prints, engineering releases, and manufacturing standards. Subsequently, communication problems, which may generate errors, are common.

Even now, errors are induced by incorrectly composed part prints that do not properly convey the intentions of the PE. Therefore, PEs should analyses composition of part prints from a critical perspective, and, if required, contact product engineers to clarify it. PEs should never assume that the part print is perfect. The tool order and the process picture communicate information from the process function to the tool design personnel [30, 31].

Therefore, the PE should have a thorough understanding of plant organization. Process engineering is a domain in which the correct attitude is as important as experience. Configuring and executing a new production process can be as challenging as integrating a new product. Every year, many new processes are launched by PEs who stay informed by attending meetings and studying relevant literature and specifications. Ignorance regarding recent developments in one's area of expertise can lead to process safety hazards and higher expenses. Process plans developed in one year can be overdue for the next year's production [32-34].

4. Conclusion

In this study, we traced the evolution of the role of the PE from continuous manufacturing to discrete manufacturing. The job profile and its responsibilities, which require mastery over multiple disciplines, were clarified to enhance sustainability and productivity. We concluded that a better structure for the professional profile of the PE can help establish the correlation between a company's expectations and interests and the states of the academic domain and the job market.

We focused on the primary inputs and outputs of the responsibilities of PEs and defined their correlations with the other functions of the plant, other projects, and product development. These aspects were clarified, with the caveat that they have to be specialized to fit the peculiarities of each plant and cannot be universalized.

The relationship between the industrial and academic domains was also analysed, and important steps that ought to be taken from both sides for mutual benefit were identified. Our conclusions indicate that the learning process must have smart objectives and quantifiable results and the curricula must include practical industrial case studies, knowledge of virtual environment, and process automation. Further, technical universities and industrial institutions should synchronize the content and velocity of development of new talent.

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