Characterization of the Operators Training Process in an Industrial Company

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Abstract

Training operators in industrial contexts is a demand that most of the industrial organizations must deal with, and engineers are the trainers in many cases. Thus, engineers may be required to deal with the development of a training environment and a competences assessment system in training settings. This paper aims to characterize strategies for planning and implementation of an operator-training process for a specific production process, namely automatic insertion lines of electronic components, in an automotive company. The developed work included the following three steps: (1) documental analysis, (2) observation of the current training process, and (3) interactions between the researchers involved in the case study and the company's collaborators. During this characterization, it was possible to identify some strategic learning approaches, and three main phases of training: the Initial Training which consists in an general explanation of the content in an integration phase; Theoretical-Practical Training which consists in a specific phase of mandatory content for operations development; and the Validation of Aptitude / Knowledge which consists in complementary content that is focused to ensure the competences development through an assessment of the trainee operator. This case study may give support to practitioners and researchers dedicated to this theme.

Keywords: Industrial training; Training phases; Engineering Education.

1 Introduction

Over the years, the world has been transformed by the industry and nowadays manufacturers are facing an increasing demand for new products and technologies. This dynamic demand requires qualified people. When the subject is production processes, it is possible to imagine a system operating in a plant with operators running complex machines (Ayarkwa et al., 2012; De Vin et al., 2017). In order to ensure a system of machines and then a good development and delivery of products to customers and market with expertise, an industrial operation is needed (Erol et al., 2016). Naturally, for this kind of operation to be successful, well-developed people are required and this development happens through the design and implementation of a training process which enables operators to do their jobs effectively (Agnaia, 1997; Rus et al., 2015).

Mavrikios et al. (2013) claim that to respond to operation role, manufacturing training should follow new approaches to prepare industry for innovative processes and for projects that seek to maintain market competitiveness (De Vin et al., 2017; Korn & Schmidt, 2015). The characteristics of manufacturing training present challenges and goals for the operators using strategies that promote synergy between the training and the industry needs. The comprehension of the requirements of the industry training and the definition of subjects and contents, could follow a pedagogical instructive approach or the training could been structured following the current company and daily work reality (Ayarkwa et al., 2012). The adaptation of the educational content and its delivery mechanisms to the new requirements of a knowledge-based manufacturing, the provision of integrated engineering competences, including a variety of soft skills, and the promotion of the innovation, are considered as major priorities of industrial training. Create an innovative training process, in the workplace, that exploits the potential of existing technology, is crucial when the focus is on developing technical and transversal skills (Ayarkwa et al., 2012; Mavrikios et al., 2013).

Bansal et al. (2010) explains that although curricula in training centres and universities have provision for industry, for example, and many training schemes are in place, especially for professional courses, some programmes have not made the impact expected and need quick changes involving the practical environment.

In order for learners to meet the skills requirements of an ever-changing labour market, adequate resources need to be invested in appropriate forms of work experience and in building up transferable skills (Ayarkwa et al., 2012). The same authors argue that learners can acquire new skills during a training process, and that training provided by organisations aims to offer learners the necessary work exposure, so they are able to adapt to the work environment during the learning journey.

Ayarkwa et al. (2012) also explain that the work environment provides an on-the-job training with a real-life job experience, making the trainee operator more aware of the needs and expectations of industry as well as making them more "ready collaborators". For the learning environment to be implemented in this training process, two fundamental characteristics are defined: personalization and adaptability (Xie et al., 2019). The personalization of the learning environment corresponds to the presentation of an environment according to the preferences and characteristics of the users. Adaptability represents the configuration according to the performance and needs of the participants as they interact with a real context.

Agnaia (1997) claim that a training development in industrial context must be addressed and deployed as any other management and process activities, arguing that it must be influenced by the other activities of the company, systems, and institutions in its environment. It is also important, for those who are trying to make the training process development supported by management, to understand their organizational environment in order to meet strategy with customer needs. Musgrove et al. (2014) highlighted an important point in the training process, related to different parts of the company as a human resource (HR). They contend that when it comes industrial training development, the HR has a role as interventionist, providing support, with a process eye and creating a sustainable talent pool through helping in the building of the necessary skills for companies success, aligned with managers to structure the adequate training (Agnaia, 1997; Dubey & Gunasekaran, 2015; Musgrove et al., 2014).

Dubey and Gunasekaran (2015) defend that training must focus equally on hard and soft skills; that is why, for them, building a sustainable industrial skill is a requirement as operators face challenges daily and problem solving must be a natural practice. The authors also contend that industry managers must hold knowledge to appreciate environmental, social, and economic dimensions. Furthermore, management must possess the desired soft skills, which include leadership, effective communication, and teamwork skills. That is why their operators skills will reflect them, at work and in strategy (Dubey & Gunasekaran, 2015; Rus et al., 2015).

Rus et al. (2015) explain that in a training process, to ensure quality and confidence, a mentor and a mentee model are very important aspects. They recommended that a right mentor must be identified for a group of mentees. It can be translated as an experienced operator able to help the industrial learners as soon as their needs come. Dubey and Gunasekaran (2015) indicate that the training "must include inbound and outbound modules". The inbound module should include theoretical inputs covering fundamentals of industrial process and evolution of the production procedures. The outbound training is a quite proven methodology to improve learners' leadership skills, empowerment, problem solving capabilities, as well as team work and effective communication skills (Dubey & Gunasekaran, 2015).

Dubey and Gunasekaran (2015) point out that the field of vocational training emphasizes individual skills through experiential learning, that is in practical context. They said that empirical learning or learning by doing something to get experience is rooted on the notion that learners have not the perception of the fundamentals that remain otherwise unchanged but is instead established and improved by experience (Dubey & Gunasekaran, 2015; Rus et al., 2015). The basis for evolving all these competences is drawn from the notion of apprenticeship, which includes a diversity of fields. Ryberg and Christiansen (2008) contend that currently, learners imitate the behaviour occurred where they received the training. Training for training will give confidence to the trainees, allowing them to enter the next stage. The final stage is where the trainees can already teach the skills they have learnt to others (Rus et al., 2015).

According to El-Bishouty et al. (2019), the skills that must be developed attend simultaneously as a guide for planning teaching-learning activities and as parameters for the construction of assessment questions and for the identification of performance. It is up to the trainer to formulate questions and label them so that the training environment can apply them to the learners to promote a progressive learning of such competences.

When learners undertake training on this process, they are subjected to an assessment. If they do not demonstrate familiarity with the process, obtained through previous experiences and learning experiences in the context of training, or are unable to answer most questions, they are guided to repeat the training. Learning tasks must be responsive to experiences and process, allow for changes and adapt to behaviour (El-Bishouty et al., 2019). The way a person understands concepts and interacts in the training environment allows him to recognize his behaviour (Azzi et al., 2020; El Guabassi et al., 2018; El-Bishouty et al., 2019; George & Lal, 2019; Jafari & Abdollahzade, 2019). This recognition can be carried out based on aspects related to the learning process, which includes cognitive, emotional, and psychological characteristics. It is important because it can contribute to improve performance, stimulate motivation, and decrease learning time, that is, to transform learning into a more positive and more effective experience.

This paper focuses on the characterization of a training process in an automotive manufacturing company, introducing what is currently performed in a real manufacturing context. It is also related to the development and delivery of a learning and training process, besides the knowledge and competences evolution of the operators and the needs related to work.

2 Training Process Characterization

The content exposed in this section presents how the training process is developed and evolves over time, as well as the competences acquired by the operator. It is possible to observe the complexity regarding the work developed and the industrial plant needs. The operation involves different steps that depends on each other and must be very well executed to ensure the quality of the final product.

2.1 Training Strategy

The complete training program that is performed, includes: (1) general content explanation in the initial training, aimed at integrating trainee operator to updated technical management guidelines (which are sensitive to organizational policies); (2) mandatory content, that is a theoretical-practical training (whose application is immediate during the execution of operations on the production line) and, finally; (3) complementary content as validation of aptitude / knowledge that consolidates the competences for autonomy of the trainee operator who is assessed to identify the intermediate or advanced level (in terms of experience and mastery of fundamentals).

This training can be an essential technique for carrying out not only workplace but also complementary activities. In that point it possible to see the alignment with the arguments of Ayarkwa et al. (2012) and Dubey & Gunasekaran (2015) presented in the introduction which explain that an effective industrial process must to be developed in a practical environment.

The essential technical training modules, i.e., the mandatory modules that enable trainee operator to perform the operations expected in the automatic insertion line, are:

1. Critical Standards - SMD (*Surface Mount Device*),
2. Laser Process,
3. SPP (*Solder Paste Printing*),
4. Glue Process,
5. SPI (*Solder Paste Inspection*),
6. Insertion Process,
7. Material Splicing,
8. MSL (Moisture Sensitive Level),
9. Reflow Soldering,
10. AOI (*Automatic Optical Inspection*) SMD.
11. 14 Quality Principles – Annual,
12. AOI SMD – Every two years,
13. X Ray - Every two years,
14. Soldering rework - Annual,

15. Selective AOI – Every two years,
16. SPI – Every two years.

Besides being given to new workers, the complementary training modules can also be attended, in some cases, by more experienced production operators. The purpose is to expand their knowledge and provide them with the opportunity to practice new experiences (with a view to achieving autonomy). The complementary training modules are:

1. Production start checklist - SMD,
2. Basic Concepts - SMD,
3. KPI (Key Performance Indicators),
4. QCO (Quick-Change Over),
5. 5S circuit,
6. Assemble and disassemble of feeders,
7. Exchanged material,
8. Autonomous biweekly maintenance,
9. Panasonic feeders autonomous maintenance,
10. NIM (Norm Internal MOE), Procedures and Standards - SMD,
11. TOP defects,
12. Minor problems resolution.

In addition to training new operators, there is an annual training plan that contains a set of mandatory update modules (refresh). Due to the analysis of the indicators related to "Main internal and customer defects", "new processes", and "process deviations", proposals for other modules are developed. When trainee operators participate in training activities, they have already had experiences in the production lines observing some experienced operators (called versatile operators) and, therefore, the training sessions aim to systematize the knowledge they already have. This provides the conceptual foundations for developing analytical skills, elimination of doubts or gaps in perception and train decision-making by presenting challenging scenarios with known occurrences, some already experienced by the participants, others not yet.

This part of the training process matches with the indications provided by Dubey and Gunasekaran (2015) and Rus et al. (2015) in the Introduction of this paper, when they explain that learners must receive training to develop soft skills in order to have a critical sense of decision and problem solving as well. The trainer conducts a survey on the previous experience of each participant, guided by the answers to ensure the effectiveness of the instructions. The trainer also ensures that the fundamental theoretical content has been fully memorized and assimilated and reads body communication and behaviour to identify signs of dispersion or fatigue.

2.2 Training Phases and Assessment

To fulfil the training process with excellence, some phases must be followed to ensure step by step apprenticeship. The process is illustrated in Figure 1 and consists of the following phases:

- Phase 1: Initial training for the integration of trainee operators.
- Phase 2: Theoretical-practical training in the workplace and in the training room:
    - During a first observation period, the trainee operator observes the versatile operator (experienced operator) at the workstation.
    - In a second supervised period, the trainee operator performs tasks at the workplace under the supervision of the versatile operator.
    - Technical training with theoretical-practical modules in parallel with the practical activities and according to the levels of aptitude observed by the supervisor.
    - Complementary training with theoretical and practical modules in parallel with practical activities.
- Phase 3: Validation of aptitude / knowledge:
    - Suitability validation based on a knowledge assessment form.

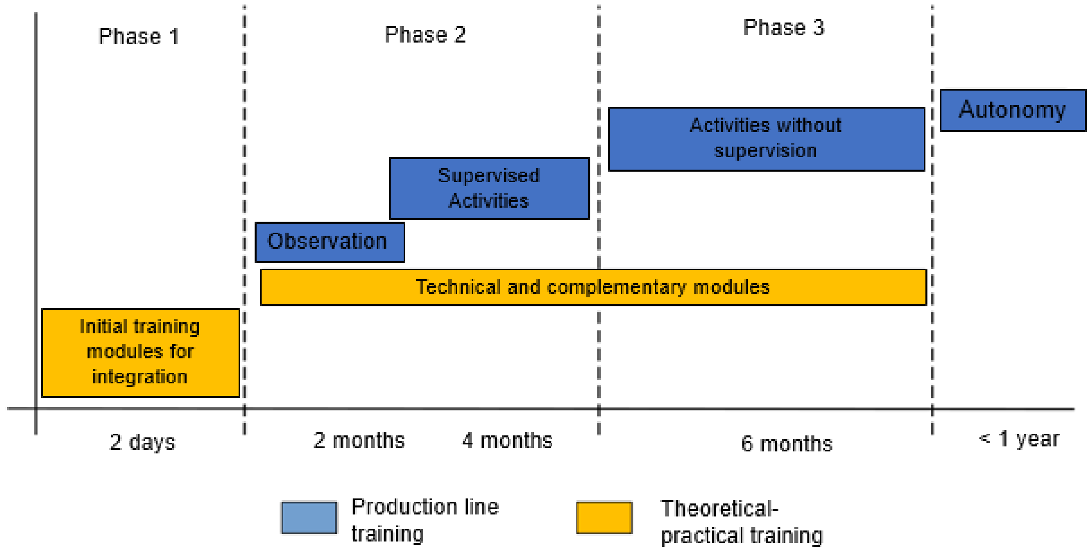

Figure 1. Phases of the training process.

The first phase lasts for two days and takes place in the classroom. The second phase consists of an initial stage of observation of the action of the versatile operator in production line, lasting two months, approximately. After the observation period, the trainee operator can carry out activities under the supervision of the versatile operator. In parallel with these sub-phases of observation and work under supervision, operators in training attend technical modules that are relevant to their experience on the production line. These technical modules are taught in a theoretical-practical format in the classroom.

Next, the contents and planning of the theoretical and theoretical-practical modules included in each phase are presented.

2.2.1 Phase 1 – Initial training for integration

This training is provided by process specialists, team / shift leaders and Quality Engineers, being a mandatory training phase that lasts two days in the classroom and the modules are distributed according to Table 1.

Table 1. Initial training for integration.

Day 1	Day 2
General presentation and considerations-SMD	Checklist start-SMD
Production process flow	Critical Standards-SMD
Basic Concepts-SMD	Ordering materials: PDA and SIIA
	Exchanged material
NIM, Procedures and Standards-SMD Process confirmation	SMD components
	Close of training

2.2.2 Phase 2 - Theoretical-practical training

In the second training phase, up to approximately 6 months, trainee operators, still in the condition of observers, must carry out the technical training modules essential for the performance of functions at the workstations and complement according to the definitions of the factory and the section. The theoretical-practical modules are divided into two parts, depending on the evolution of the skills of the trainee operator. The modules of part 1 are shown in Table 2.

Table 2. Technical and complementary training – part 1.

Day 1	Day 2	Day 3
Material splicing	Glue Process (Ipag and Asymtek)	Autonomous biweekly maintenance
Laser (after 2 weeks)	5S circuit	Panasonic feeders autonomous maintenance
Assemble and dismantle feeders	TPM (QCO, OEE, KPI)	

The part 2 modules are shown below in Table 3.

Table 3. Technical and complementary training – part 2.

Day 1	Day 2	Day 3	Day 4	Day 5
Solder Paste Printing	SPI	MSL	AOI SMD	TOP of defects-SMD (internal and customers)
	Validation of SPI images	SMC		
	Insertion Process	Reflow Soldering	Images validation	Resolution of minor problems

2.2.3 Phase 3 - Validation of aptitude / knowledge

Phase 3 begins when the trainee operator performs the activities without the need for supervision and ends after the validation of the aptitude form. After this training period of phase 1 and phase 2, the operator in training is assessed by taking the aptitude exam and is also asked to complete an assessment form of the training process itself. Once approved, the cuff that identifies the training condition is removed, thus allowing the trainee operator to carry out the activities without supervision. At this stage, trainee operators still participate in relevant technical training modules considering their level of experience.

The trainee operator is considered fully autonomous after approximately one year of experience. It was possible to observe in this practice of the industrial real context, what was explained by Agnaia (1997), and described in the introduction section, about the importance of activities supervision and then the need of let the learner do the tasks with autonomy.

However, in this third phase, which takes place in a period of up to 6 months approximately, content review activities identified in the aptitude exam may be envisaged.

3 Discussion

Regarding the efficiency of the current training process, the integrating and training strategy of the trainee operators in the automatic insertion lines is proving to be effective looking for the current process. It is based on the direct observation of versatile operators, team leaders and support personnel, namely technicians, process specialists and Quality Engineers. However, the process, from the entry of trainee operators until they reach full autonomy, is time consuming, with an average duration of 1 year, but once one sees this as a process that can be improved, it is possible to find the path to reduce the time required to reach autonomy.

This process involves many human resources and equipment, and it is necessary to invest a lot of time in training, support, monitoring and clarifying questions. Thus, it is understood that the efficiency of the current training process can be improved by at least two point of view:

- Compressing the total duration of the training process.
- Using digital learning simulation systems, aiming to use fewer resources.

The first one will benefit from a business process perspective applied to the training process. As it is well known in industry, a continuous improvement perspective applied to processes will allow reducing throughput time and utilization of resources. Thus, the authors' first proposal would be to create a new model of the training process(es) and make direct links between the identification of required competences from the production system itself to the way the training will be designed, implemented, assessed, and evaluated. In summary, the first recommendation would be to develop a process view of the training process applying the best-known solutions for effective learning. As an example, there would be a good opportunity to implement instructional design (Arghode et al., 2018; Branch, 2009; Edmonds et al., 1994) concepts and active learning (Freeman et al., 2014) methodologies as higher learning effective solutions.

A digital learning simulation system, aiming to use fewer resources, could be focused on Augmented Reality (AR) and Virtual Reality (VR). Such a VR/AR environment should not be just an interaction environment; the principles of Game-Based Learning (GBL) must be considered and corresponds to the modelling of each participant as a player. The player acquires knowledge as it interacts with content and activities presented in the style of a game or in a storytelling structure, in which participants are confronted with challenging situations and need to solve problems to move forward. Game Design elements can include collaboration, roles, objectives, challenges, exploration, storytelling, complexity, competition, strategy, communication, feedback, augmented reality, control, interactivity, realism, rules, frameworks, curiosity, expression, involvement and rewards (Jafari & Abdollahzade, 2019; Paravizo et al., 2018).

As could be observed from the content exposed in the introduction section, until the understanding of the real context, the industrial training process is not a set of operations that are linearly interconnected. The employees already bring with them some experience in the production line, despite being very limited and strictly mechanical (repetition). Thus, training does not aim to train the performance of the sequences of activities, but rather to systematize previous knowledge with concepts, connections and relationships that give meaning and offer a sense of work organization. Thus, the role of the trainee operator is very important because his/her job consists, practically all the time, of probing weaknesses in perception, gaps in systematized knowledge and tests, in relation to the decisions necessary to face the events that are predicted in production line.

4 Conclusions

An important aspect observed is the conduct way that the company, and the engineers assuming the trainer role, exercise during the training to choose the best strategy to maintain the attention of those present and ensure that the knowledge has been properly assimilated. That part of the study confirms what was explained based on the authors cited in the introduction section, which means a strategy designed to provide the best way for the trainee operator acquire knowledge and develop competences. In addition, the process of follow-up to ensure efficacy and the engagement of tasks may help the operator to develop soft skills. This type of development is a kind of bonus to the trainee operator and permits to fulfil gaps solving problems that appear in daily work at the company. The assessment is performed to understand if the operators acquired the knowledge in depth to develop their work, but could also assess soft skills if that is a company goal as well.

The learning environment must be open, meaning both the training path, as well as the interaction with the factory environment in the daily work as needed. Therefore, the training model for industrial operators must have sufficient resources to guarantee learning and skills development. However, the natural evolution of the production processes require the development of new operators, and this requires the involvement of process engineers and specialists in the design and deployment of the training process.

An important conclusion of this work is that the training processes in an industrial environment must be considered in the same way as the other processes in the company (e.g., production processes) that are constantly analysed in order to be improved (continuous improvement). This is the only way to develop training systems that are not static, but that can evolve according to the changes that occur in the surrounding context. Thus, it becomes evident that the reduction of the time needed for trainees to develop the necessary skills to achieve the desired autonomy is only possible if the training processes are also subject to continuous improvement efforts.

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