Industrial Training Qualitative Evaluation with Fuzzy Logic and an Experience Classification Method

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DOI: https://doi.org/10.5281/zenodo.5098313

Abstract

It is usual that companies must develop their own training processes, adaptable to their own production systems. In fact, the evaluation of the training process is a function of significant importance and must guarantee means for the identification of demands for corrective actions and for a procedure that ensures the continuous evolution of the process, therefore, that meets a dynamic of continuous improvement. The evaluation of a training process aims to provide information to support the decision making of the trainer, the process manager and other decision makers. This paper aims to propose a model of qualitative evaluation for industrial training based in fuzzy logic and a method of classification of training experiences. This training evaluation model considers the level of uncertainty that exists in qualitative responses (from trainees) and based on this, proposes a method for defining priorities for decision-making and carrying out improvement actions with the aim of evolving the training program. This action research was developed through a theoretical framework guided by the characterization of the context and the opportunity for improvement identified in this characterization, development of the model, and finally in the application of the model in an industrial training process.

Keywords: Industrial training; Training evaluation; Fuzzy logic.

1 Introduction

According to Loch et al. (2018), training in the workplace has received attention from researchers and practitioners in industry because it has been directed at meeting the implications of the increased complexity of industrial machinery. Training processes are aimed at developing competencies to perform tasks or carry out procedures proper to the work act. Ilyas & Semiawan (2012) advocate collaborative action between industry and education to develop means and implement effective means for effective excellence in manufacturing.

For Hecklau et al. (2016) the performance and competitiveness of an organization depend heavily on human resource management and one of the most important elements of this functional area is human resource development. According to the authors, human resource management can be defined as a strategic approach to the development and employment of a qualified workforce that is highly committed to the company's objectives. This vision inevitably goes through the action of professional education, learning and training of people individually or in teams, in aspects that are sensitive to the organizational strategy and therefore to the performance of any organization in terms of competitiveness and operational goals.

There are several models for developing and implementing training processes in the industry. Among them one can cite as main ones: Production-Based Education – PBE (Ilyas & Semiawan, 2012), Work Based Learning – WBL (Garnett et al., 2016; Helyer, 2015), Learning Factories (Abele et al., 2017), Lean Production Training (De Vin et al., 2017). Many other proposals originated from successful private experiences are disseminated in the literature. All these models consider the evaluation of the training processes.

Carlucci et al. (2019) argue that evaluation, especially in the field of education, has two distinct dimensions: (i) identification of problems or opportunities for improvement (that require corrective actions), and (ii) evaluation at a higher level of abstraction, aiming at strategic planning for the realization of higher order actions, i.e., that results in the evaluation of the model.

An important element of the evaluation of the training process is the subjective assessment of both trainees and trainers. Therefore, Carlucci et al. (2019) proposes a framework to adequately analyse the quality of the

teaching process in the light of the imprecision and uncertainties present in subjective assessments. Once the various courses planned in the training process have been completed, the participating agents must answer a questionnaire on their perceived quality, which can be observed as the participants' judgment of their experience in the process, either as trainees or as trainers.

The instrument integrates two methods, the u-control chart and the ABC analysis using fuzzy weights. By means of the control charts, trainees' assessments are analysed to detect courses that are outside the control limits, and ABC analysis using fuzzy weights deals with the imprecision and uncertainty of those assessments in order to provide a risk map of potential areas for improvement. In general, the authors present a management tool capable of indicating the need for short-term corrective measures, by means of the control charts, and pointing out areas that have potential for improvement in the long term.

Unlike propositional logic and predicate logic, also known as Boolean logic, in which equations are composed of arguments with unambiguous quantification, fuzzy logic, as stated by Williams (2009), proposes inferences that are closer to the human way of thinking. For example, in propositional logic, to analyse the height of a person, one considers the results “high” and “low” and establishes objective values as criteria for choice to fit the situations in such classifications. Fuzzy logic is able to accommodate nuances of perception about these qualities and admits gradations between them in order to predict other qualities such as “very low”, “low-medium”, “medium-low”, "medium", "medium-high", “high-medium” and "very high". Therefore, there are no truths, but degrees of truths, or different degrees of association. In Boolean logic the results are 0 and 1, while in fuzzy logic, in addition to the absolute values 0 and 1, any value in between is possible.

Nakashima et al. (2004) clarify that the application of rules based on fuzzy systems for the control of problems is common, and more recently the application of these same rules for the classification of patterns has emerged. The authors state that weight is a mathematical tool to enable this application. A weight is assigned to each given pattern based on the class distribution of its neighbouring patterns so the number of neighbouring patterns of the same class determines its values proportionally. In fuzzy rules, patterns with small weights are not considered in the classification.

It is argued in this article that one should consider training as an organizational process, since if the objective is the organization's performance, it must be conceived for the organizational architecture and based on it, in a way that it is organically integrated with management actions and linked to the decision-making process.

Therefore, in a complementary way to the good practices already established in traditional models, the training process is also considered as a set of integrated activities that aim to meet a goal in the first instance that is aligned with the objectives of the various organizational instances. The tool that allows planning and managing this kind of perspective is the so-called Instructional Design that can be operationalized by the ADDIE concept – Analyze, Design, Development, Implement and Evaluate (Branch, 2009; Edmonds et al., 1994; Gibbons & Yanchar, 2010; Hokanson et al., 2008; Reiser, 2001).

Based on the ADDIE concept, the evaluation activity in the training process is thought and executed in an integrated and aligned way with the other activities. In this article, it is intended to present a model of qualitative evaluation for industrial training based in fuzzy logic and a method of classification of training experiences with ABC analysis as a strategy to promote improvements responsible for the evolution of the model and the training process.

2 Methodology

This article is the result of the observation research procedure followed by critical analysis supported by a literature review for the purpose of theoretical background and study of precedents. Guided by the experience gained during the immersion process of the authors in the application environment and by previous experiences, a search for references was conducted. The research process went through two stages, namely: (i) the immersion stage in the environment where the improvement actions were intended, and (ii) the solution building stage, based on the knowledge and previous experiences of the researchers and practitioners, besides the execution of the improvement actions in a collaborative way with the professionals. The construction of

the solution, including research on similar precedents, was guided by the need to make the notion of expected quality of the training process, observable and tangible. This provides a way to develop an evaluation instrument that would take into account the subjectivity of the participants as to their level of satisfaction with the training experiences so that managers would have an effective resource for decision-making. The solution reached is based on fuzzy logic and experience classification methods.

3 Expected quality of training

In the previous training process, the evaluation of the training by the trainees was carried out as illustrated in Table 1.

Table 1. Evaluation of training by trainees (previous process)

Please evaluate the courses using the followed scale: 1 – It needs of revision; 2 – It coult be improved; 3 – It does not need of revision.

	Day	Courses	Evaluation		
			Content	Trainer	Total
Week 1	1	Presentation	2	3	2
	2	Basic Module	3	3	3
	3	Folder Printing	3	3	3
	4	Ordering materials	2	3	3
	5	Insertion process	2	3	2

The disadvantage of this evaluation is the difficulty in identifying structural change needs of a training, i.e. it requires revision at the level of the dimensions of Instructional Design – Analysis, Design, Development, Implementation and Evaluate. The practical result of the previous evaluation model confirms the aspect pointed out in the literature review. That is, the evaluation expressed the experience of each trainee and served to identify isolated occurrences, of difficult treatment, because it reached the knowledge of the managers only after it had happened and, in general, they were of the type that were not repeated in the same conditions and with the same effects.

4 Results

A new model of subjective evaluation was developed and adopted, which can identify problems of greater complexity. Fuzzy weight is recommended because of the degree of imprecision and uncertainty that subjective evaluations of trainees have. The function membership is illustrated in Figure 1 and shows intersections between responses. Thus, as a base for modelling, a Likert scale from 1 to 4 was defined where the options mean "Definitely yes" (*dy*), "More yes than no" (*my*), "More no than yes" (*mn*) and "Definitely no" (*dn*). The *dy* answers were given weight 1, the *my* answers weight 0.5 and the others weight 0 (see next).

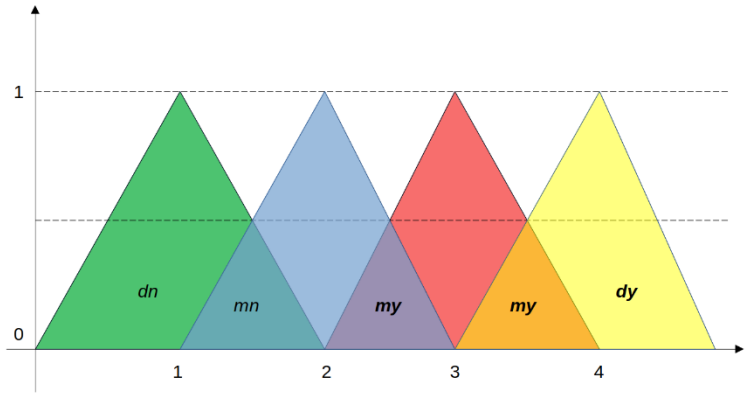

Figure 1. Membership function

It is suggested that responses should also be subjected to an ABC curve analysis, as this is a Pareto analysis used to categorize data according to degrees of importance. Based on the authors Carlucci et al. (2019), the distribution of classes should serve to build a risk map defined as follows: A (low risk) 0-75%; B (medium risk) 75-90%, and; C (high risk) 90-100%.

An example of the new questionnaire developed can be seen in Table 2 and an example of the data analysis process is represented in Table 2.

Table 2. New model of questionnaire

Please evaluate the training listed below. For the question "Does it need revision?", please use the following scale: DY – Definitely yes MY – More yes than no MN – More no than yes DN – Definitely no			
Day	Course	Content	Trainer

The new model considers the entire evaluation history, at least 99.9997% of the evaluations in order to comply with the Six Sigma standard recommendation for process monitoring (Carlucci et al., 2019). The scale has changed, and one should now answer the question: does the training need revision? The answers should be "definitely no" (dn), "more no than yes" (mn), "more yes than no" (my) or "definitely yes" (dy).

The answers dn and mn were discarded in the analysis and the weights 0.5 and 1.0 were applied to answers my and dy, respectively. These weights are applied to balance the scores according to the existing diffusion in subjective questions. The calculation of the ABC curve was parametrized as follows: A – 0-75% (low priority), B – over 75% and under 90% (medium priority) and C – over 90% (high priority). With this, managers have an efficient tool to prioritize the reconfiguration of training.

An important factor in using the ABC curve to prioritize course reconfiguration actions, in response to subjective evaluation, is the slow response time for improvements to begin to affect the curve substantially since it reflects the processing of historical data and it is natural that new positive assessments remain diluted in older negative assessments. This effect is expected and important for the methodology, since the proposal involves a permanent monitoring of the measures that ensure a continuous improvement so that the perspective of prioritization refers not only to corrective actions, but also to the analysis and monitoring of the effectiveness of corrective actions. In other words, a negatively assessed course needs improvement actions, and a period of monitoring the effects of these actions until the improvement becomes consolidated. The evidence of the improvement consolidation is the grade changing from A to B, or from B to C.

Table 3. Evaluation of training courses, distribution of data

Training evaluation																				
Question: Does the training need revision?																				
	Total responses								Fuzzy											
	Content				Trainer				Content				Trainer							
	DN	MN	MY	DY	DN	MN	MY	DY	DN	MN	MY	DY	DN	MN	MY	DY	Points	%	Sum %	Class
Opening of stop latches	40	2	1	1	40	3	1	0	0	0	0,5	1	0	0	0,5	0	2	0,67	0,67	A
Ordering materials	40	2	1	1	40	2	2	0	0	0	0,5	1	0	0	1	0	2,5	0,83	1,50	A
Insertion process	40	2	0	2	40	3	1	0	0	0	0	2	0	0	0,5	0	2,5	0,83	2,33	A
Coil splices	39	2	2	1	39	3	2	0	0	0	1	1	0	0	1	0	3	1,00	3,33	A
Starter Chcklist	25	10	7	2	40	3	1	0	0	0	3,5	2	0	0	0,5	0	6	2,00	5,33	A
Assembly of feeders	25	10	5	4	39	4	1	0	0	0	2,5	4	0	0	0,5	0	7	2,33	7,67	A
Folder Printing	15	16	10	3	39	3	1	1	0	0	5	3	0	0	0,5	1	9,5	3,17	10,83	A
Production process flow	15	16	6	7	38	4	2	0	0	0	3	7	0	0	1	0	11	3,67	14,50	A
QCO SW + HW	20	9	8	7	40	4	0	0	0	0	4	7	0	0	0	0	11	3,67	18,17	A
Glue	16	12	10	6	40	4	0	0	0	0	5	6	0	0	0	0	11	3,67	21,83	A
Critical standards	10	15	12	7	40	3	1	0	0	0	6	7	0	0	0,5	0	13,5	4,50	26,33	A
Training	10	16	9	9	39	4	1	0	0	0	4,5	9	0	0	0,5	0	14	4,67	31,00	A
Confirmation of process	4	20	10	10	40	4	0	0	0	0	5	10	0	0	0	0	15	5,00	36,00	A
MSL	15	8	11	10	40	4	0	0	0	0	5,5	10	0	0	0	0	15,5	5,17	41,17	A
Presentation	14	10	9	11	40	4	0	0	0	0	4,5	11	0	0	0	0	15,5	5,17	46,33	A
Laser	7	17	10	10	38	4	1	1	0	0	5	10	0	0	0,5	1	16,5	5,50	51,83	A
Confirmation of proceedings (2)	11	10	13	10	40	4	0	0	0	0	6,5	10	0	0	0	0	16,5	5,50	57,33	A
NIM's, procedures and standards	5	15	15	9	39	4	1	0	0	0	7,5	9	0	0	0,5	0	17	5,67	63,00	A
SPI	7	12	15	10	38	4	1	1	0	0	7,5	10	0	0	0,5	1	19	6,33	69,33	A
TPM	0	15	15	14	40	4	0	0	0	0	7,5	14	0	0	0	0	21,5	7,17	76,50	B
Basic module	4	12	12	16	40	4	0	0	0	0	6	16	0	0	0	0	22	7,33	83,83	B
5S circuit	2	10	20	12	39	3	2	0	0	0	10	12	0	0	1	0	23	7,67	91,50	C
SMC	4	6	17	17	40	4	0	0	0	0	8,5	17	0	0	0	0	25,5	8,50	100,00	C
												Total					300			

In Table 3, the first column contains the courses/modules that are taken and in the next two columns, grouped under "Total responses", there are 44 responses distributed among the scales. These numbers are processed by applying the defined weights and the results are presented in the corresponding columns, grouped under "Fuzzy". This way it is possible to perform the summation, calculate the percentages and perform the Pareto classification. It can be observed that the "SMC" course has a higher priority level for the managers' actions. The values of other courses such as "Confirmation of process" or "Laser" could lead managers to decide to plan interventions in these courses to the detriment of others that obtained a higher priority level since they have low values in the smaller scale, and greater distribution in the other scales, which would make interpretation difficult without the aid of the weights. The conclusion obtained with this proposed experience ranking would not be easy to obtain without fuzzy analysis since the distribution of responses alone does not provide an objective measure of evaluation.

5 Recommendations and Final Remarks

Training in the workplace is an important strategy for organizations in the management of human resources because the qualification of the workforce developed externally is often not enough to account for the complexity of certain productive systems, as well as to introduce employees to the decision-making policies and organizational culture. Therefore, in order to achieve effective results, it is necessary that training is understood as a business process, therefore, designed in a horizontally and vertically integrated way, and articulated in the organizational architecture. In this way, the training process becomes a visible structure, from which it is possible to evaluate its alignment with the strategic objectives, and which ensures clarity as to operations, roles, responsibilities, results, expected performance, and therefore its indicators. From this perspective, the evaluation goes beyond the binary criterion of quality and starts to consider different instances in which operations aimed at correcting problems whose effects are immediate and actions that must be taken for the evolution of the process are applicable. In this perspective, the concept of continuous improvement includes in one axis the elimination of defects, and in the other the search for improvement, which means reaching new standards of differentiation. This article aims at this second dimension of quality perception and one found that fuzzy logic can be a suitable instrument for this purpose since it aims to provide means for systems to enable evaluation conditions and decisions closer to the way people think, that is, that do not discard subjective judgments and nuances of perception that are also important, especially in the notion of quality. The prioritization technique, namely the ABC Curve, is presented in this article as a technique for classifying training experiences in order to support the manager in making decisions to obtain results of greater impact on the perception of quality in the training process by its participants.

6 Acknowledgments

This work is supported by: European Structural and Investment Funds in the FEDER component, through the Operational Competitiveness and Internationalization Programme (COMPETE 2020) [Project nº 39479; Funding Reference: POCI-01-0247-FEDER-39479]

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