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A fuzzy set scale approach to value workers participation and learning

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ABSTRACT

This article reports the process of building a fuzzy set scale in order to value workers participation and their learning through a technical improvement project in metallurgical plants. The process starts with a practical question which stems from workers: 'How can we value our own participation in collective improvement project and the learning related to it?' Participation is structured in three subsets: participation in planning, in designing and in implementing the improvement project. These three subsets are aggregated in a global participation set. Learning is structured in two subsets: individual and group learning in the form of fuzzy inference system Mandami type. Participation (causal condition) constitutes a subset of achieved learning (the outcome), a sufficient but not necessary condition for the outcome. This subset relation is highly consistent providing support for the statement "participatory projects enable meaningful learning" between workers and organization.

Aproximación a una escala borrosa para valorar participación y aprendizaje de los trabajadores

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RESUMEN

Este artículo presenta el proceso de construcción de una escala basada en conjuntos borrosos que permita valorar la participación de los trabajadores en proyectos de mejora técnica en plantas metalúrgicas y el aprendizaje logrado en tal experiencia. El proceso se activa con una pregunta práctica propuesta por los trabajadores: ¿Cómo podemos evaluar nuestra propia participación y el aprendizaje relacionado a los proyectos de mejora emprendidos colectivamente? La participación está estructurada en tres sub-conjuntos: Participación

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en la planificación, el diseño y la implantación de los proyectos de mejora. Estos tres subconjuntos se agregan en un conjunto que agrupa la participación como un todo. El aprendizaje está estructurado en dos subconjuntos: aprendizaje individual y aprendizaje grupal. Ambos conjuntos siguen la forma de un sistema de inferencia tipo Mandami. La participación (condición causal) constituye un subconjunto del aprendizaje logrado (resultado) y es una condición suficiente pero no necesaria para el mismo. La relación de subconjunto es altamente consistente para sostener la premisa 'los proyectos participativos facilitan el aprendizaje significativo' en los trabajadores y por ende en la organización.

Introduction

In spite of some in-depth studies about workers participation (Bonavia and Quintanilla, 1999; Ness & Azzellini, 2011) few of them reflect a valuation of that participation and the learning related. Participation programs related to quality improvement and productivity involving worker participation are promoted from management. Albalate (2004) values worker participation in technology in the auxiliary automobile industry (Catalonia, Spain) considering managers opinions' not workers opinions'.

In a participative context, workers demand more participation at different levels of the management decision process and areas. Technological projects are in the workers' interest, and participation in the planning, design and implementing activities of technological improvement is their goal.

This study develops a fuzzy scale approach to value the degree of workers' participation in planning, designing and implementing technology improvement projects related to the respective learning achieved.

Three methods are involved in this study: the construction of continuous fuzzy sets through an inference system of the Mandami type to develop the scale approach, the "receiver operating characteristic" (ROC) curve which validates the inference systems, and the use of Consistency and Coverage Index for evaluating fuzzy set relations (Ragin, 2006).

The article is structured as follows: after introduction a theoretical framework considers worker participation and learning in the micro-level of organizations. Then the method and the data source are developed. Next section shows the findings from the study and develops the discussion of the fuzzy sets analysis in a participatory and learning environment. Finally the conclusions are presented followed by the limitations of the study and suggestions of future research opportunities.

Workers participation and micro-level organizational learning

The starting point for this research is an examination of the context that enables workers to participate and learn through technical improvement projects. The literature reviews consider studies about technological learning through Socio-Technical Adequacy. The process is completed considering research literature about measuring worker's participation and learning in a micro-level of the organization.

Workers participation context and learning

There are different approaches (Bonavia and Quintanilla, 1999) in the studies about workers participation: participative management, industrial democracy, participation in the context of quality improvement and productivity programs like "fashion management" programs (Rolfsen & Knutstad, 2011) which managers, technicians and engineers promote without the decision of workers. This study considers context participation from workers perspective, where they take the initiative in order to participate looking for more democracy in the decision making in organizations, an old claim from workers' perspective that intends to achieve more inclusion and participation in the management of the firm (Ness & Azzellini, 2011).

In the last decade, studies and proposals present enterprises democratization as a way of looking for alternative solutions to the complex problems facing the world of labor and capital. Ness et al. (2011) document a geographical, historical and political journey of democracy in the factory through workers' control. Wolff (2012) suggests the idea of Workers' Self-Directed Enterprises (WSDEs) to allow democracy at work, the environment that could enable the initiative of workers for participation beyond their formal activities in the shop floor.

Historically, formal workers participation in decision-making occurs through their representative in the Supervisory Board or the Works Council. The German case is the oldest and best known experience that continues until today and influences companies in the European Union (Council Directive, 2001/86/EC; European Parliament, 1997).

Workers develop activities to solve technology problems in workplace as a particular case in their organizational participative experiences. Feenberg (2002, 2006) critical contributions to the democratizing of technology approach emphasizes technology as a strategy for the transformation of society through three transitional processes "socialization, democratization and innovation" (2002, p. 149): a way which allows workers to participate and learn.

Following this perspective, in the field of sociology of technology, Lahera (2004) makes relevant contributions in the study of participation from the perspective of workers' through informal learning that influence in changes associated with technology automation.

Bialakowsky, Grima, Costa, and Lopez (2005) focus their studies on the Argentinean workers' recuperated enterprises in a new perspective of workers' participation: inclusion and democratization of the processes associated with technology and a change in the processes of accumulation and distribution of knowledge. In short, participation through the democratization of the firm seeks the integration of workers in processes that have been reserved to technicians, engineers and managers (Ataöv, 2007).

Similar cases where workers demand more participation in enterprises decision making happen in Venezuelan context, where the article 70 of the Bolivarian Constitution of Venezuela (Asamblea Nacional, 2000) is the basis for people's participation. The text declares different forms of participation such as self-management, co-management or cooperatives. In spite of that, participation widely extended in all the country, few studies follow workers participative experiences (Cova, 2011).

Workers' participation experiences under study are developed in three Venezuelan metallurgical enterprises, at the micro-level workplaces where they took the initiatives to solve a particular problem or addressing a technical situation in their natural spaces whose work features are similar to the "community of practice" formalized by Wenger (2001). His proposal considers the following premises: the social being as an essential aspect of learning, knowledge as search capabilities, participation as an active search for those skills and learning as a meaningful ability to experience the world.

Focusing the participative workers' experience in technology as a "community of practice" allows the study of tacit knowledge sharing at the micro-level of the organization. Such knowledge sharing is the result of the equally dialogic relations (tacit to tacit) with a high exchange of knowledge among the lowest ontological levels (individual and group) of the organization (Nonaka & Takeuchi, 1995). Kawamura (2007) emphasizes the need for expanding Nonaka and Takeuchi's original model of organizational knowledge creation by incorporating the concept of "community of practice" to reinforce knowledge creation. In spite of the advancement in organizational knowledge creation (Firestone & McElroy, 2004; Nonaka & Toyama, 2003; Nonaka & Von Krogh, 2009), who incorporate the dialectic thinking, other organization learning and knowledge management theories, few studies evaluate the impact of tacit knowledge sharing at the organizational micro level (tacit to tacit).

This tacit knowledge sharing and learning emerges in the improvement projects undertaken by workers through their participation in technology in the way considered in the Socio-Technical Adequacy process approach (Dagnino, Brandão, & Novaes, 2010) as a form of technology and organizational improvement. The process of Socio-Technical Adequacy means different ways of improvement and changes in the factory through workers' initiatives: partial adaptation of the factory to their interests, appropriation of knowledge about the productive process (use), repair and adaptation of machines. From project to project, through participation, workers learn technology skills and become empowered.

Wang and Ellinger (2011) analyze trends in organizational learning and remark that "the connection between individual learning and organizational learning still lacks empirical investigation" (p. 514). Because individual do not work isolate, the study of this connection must consider the individuals interaction and grouping in the organization (group level), for example: interaction in their workplace to do formal or informal activities like the cases under study.

Within a framework of democratic participation, organizational learning requires generation of creative proposals to encourage the exchange of knowledge among workers. The formalization of these proposals may results in learning socialization through the whole organization.

Evaluation of workers participation and technology learning

Chiva, Alegre, and Lapiedra (2007) report that some research has been conducted to measure organizational learning capabilities taking into account the facilitating factors for organizational learning. Through the literature review they found that the most underlined facilitating factors consider multiple dimensions: experimentation, risk taking, interaction with the external environment, dialog and participative decision making. However, these measures refer to a general evaluation of the organization as a whole and did not take into account the micro-level performance.

Albalate (2004) research provides the criteria for measuring the degree of participation of workers in this study. He defines categories of participation ranging from no participation through consultation (unidirectional and bidirectional) to self-management as an expression of greater participation and democracy. The study suggests self-management as a form of higher grade participation, the form of collective management of highest value and an old aspiration of many workers worldwide. In the sense stated by Rechberg and Syed (2014) participation also implies that workers are actively engaged in conceiving, designing and implementing the technological improvement projects.

In other hand, some recent papers reflect the interest in micro-level measures related to workplace learning in a structured environment (Siadati, Gaŝević, & Hatala, 2016). But, they emphasize that workers' learning through daily activities is informal and autonomous with high degree of knowledge workers control. Our research interest is in follow this non-structured micro-level learning process through the relationship of workers participation in extra daily activities initiatives to solve technical problems in their workplaces and the learning achieved as a collective or community.

Socio-Technical Adequacy process (Dagnino et al., 2010) put on the debate about the kind of learning workers look for: a meaningful learning that strengthen their knowledge in order to participate with managers and technicians in technical problem solving. Vieta (2014) studies found this kind of informal learning which emerges from their own initiative in worker-recuperated enterprises as transformative learning organizations exploring informal and collaborative learning processes. He reported "some degree of positive transformation in their actual collective decision-making skills" (p. 196) during workers informal learning processes catalyzed by struggles related to recuperated enterprises.

Therefore, this study finds research opportunities in two directions: the need to develop a way to value these micro level processes, and showing the emergent relations between participation conditions in a technology improvement project (planning, designing and implementing) and the learning achieved.

Method and data

The research uses an accompanying strategy from participatory action research (PAR): the 'proximal research' through educational-research workshops and systematization of experiences considering the perspectives and needs of stakeholders (Cova, Arzola, & Rodríguez-Monroy, 2015).

The goal of these workshops is the promotion of participative teams (collectives of knowledge) to enable technology democracy and knowledge sharing through improvement projects in their respective factories. Researchers and workers follow a cycle PAR process of action and reflection through strategies of education, inquiry, organization and communication (Cova, Rodríguez-Monroy, Arzola, & Dávila, 2015). Under this PAR environment workers elicit their perception about the degree of participation and learning in the improvement projects which facilitate the fuzzy approach application. This approach considers developing a fuzzy scale with workers, the calibration process, the fuzzy set analysis and a validation test for the scale proposed.

Data sources

Data source comes from these participatory educational research workshops with Venezuelan metallurgical workers who promote twenty-three improvement projects as case studies. Participatory action research with workers follows two phases: in a first step, workers provide their perception about ranging the value of different forms of participation and learning categories. In a next step, workers evaluate the degree of participation and learning associated with their own projects using a fuzzy scale under a set-theoretic approach (Fiss, 2007) in which the relationship among different variables is considered in terms of set membership. Set theoretic allows set relations between verbal statements common in most social science theories. The membership in sets may use dichotomous values (membership/non-membership) related to crisp sets or membership scores ranging from ordinal up to continuous values related to fuzzy sets (Fiss, 2007; Ragin, 2000, 2006).

Developing a fuzzy scale with workers

The meaning of participation and learning like other concepts in natural language imply certain vagueness (Lawry & Tang, 2009; Zadeh, 1965, 1971). Vagueness suggests gradation, and this gradation is not in the field of conventional variables. Vagueness is associated with a kind of linguistic expression that has uncertainty in meaning. Fuzzy sets theory continues to reassert itself as the formalization of human skills related to decision making in an inaccurate information environment and the realization of physical and mental activities without steps or computations (Zadeh, 2008).

Organizational and management recently studies apply fuzzy sets as a method of measure some management strategies: the evaluation of knowledge management capability of organizations combining fuzzy sets and multi-attribute strategies to evaluate the performance and the degree of importance, mostly qualitative attributes and aggregation (Fan, Feng, Sun, & Ou, 2009). Medina, Zuluaga, López, and Granda (2010) use fuzzy inference systems of the Mandami type (Mandami & Assilian, 1999) as an approach for measuring the intellectual capital in order to overcome the incompleteness of conventional models. Also, Esquivel, Benjamín, and Bello (2014) propose the implementation of fuzzy sets to evaluate the results and impacts of training activities in organizations.

These researches give the basis for implementing a strategy to build a fuzzy scale for workers participation and learning valuation. The scale needs to be structured in fuzzy sets and develop a system of aggregation (Mandami inference system) which has to be test and validate through the "receiver operating characteristic" (ROC) curve.

In the fuzzy sets approach, it is necessary to define a value of 0 as fully out of the relevant set and a value of 1 as full set membership. In each sub-set category of participation or learning, the value of set membership ranges from 0 to 1 expressing a degree of membership. These values come from the direct contact with stakeholders and the use of substantive knowledge in the creation of the measure for participation or learning. Names for a fuzzy subset of the universe of discourse emerge from their natural and living language.

Calibration

The notion of a calibrated measure refers to determine qualitative thresholds for full membership, full non-membership and intermediate values in order to assign the degree to which different cases belong to a set under study (Ragin, 2000, 2008).

Verkulien (2005) points out the problems of calibration through direct assignment: interpreting what a membership value means, abstraction of concepts, different sources of bias, individual differences among subjects assigning membership. In spite of that, the direct assignment membership method basis on technical expertise and substantive knowledge provides a way of knowledge sharing in a participatory and small N context when a technical improvement project is being developed.

All sub-sets in partial participation, whose basis is the Albalate (2004) study, have the following labels: get information, co-decision and all-member decision. Table 1 shows the linguistic categories, related to participation, developed with workers. The threshold for full membership is (1) for each participation labeled subset, the threshold for full non-membership is (0), and the other points including the cross-over point membership functions (MF) are triangular functions through a gradual transition from membership to non-membership in the sense of Zadeh (1971, p. 160) when he refers to "the fuzziness of meaning" in a fuzzy class.

Global participation measure is the result of the aggregation of partial participation sub-set (participation in

Table 1 – Linguistic categories related to participation.

Sub-set	Description	Full (0) non-membership	Full (1) membership
Get information	The information received and required for the execution of the improvement for both the project leader and the other participants	0, 35	20
Co-decision	The project leader and responsible inquire and decide with the rest of the group	30, 75	55
All-member decision	Anyone in the group makes proposals on improving and the decision process is open to all	70	100

Table 2 – Linguistic categories related to learning.

Categories	Description	Full (0) non-membership	Full (1) membership
Irrelevant	It lacks interest for the realization of technical improvements	10	0
Weak	Little knowledge for improvement project	10, 40	25
Necessary	The necessary knowledge to perform the tasks that the improvement project need	40, 60	50
Sufficient	Explicit learning that others can be achieved	60, 85	75
Meaningful	Learning that allows changes and enhancements in the project of interest is achieved	80, 100	100

planning, designing and implementing the improvement project) through a Mandami type inference system. Global participation sub-sets label are low, medium and high in correspondence with workers natural language.

During the survey, workers relate their participation, the postulate causal condition, with the learning achieved about technology, the desired outcome, in each project or case. The learning achieved, as a target set, is the aggregation of individual and group learning. The learning scale considers five subsets: 'irrelevant' learning, 'weak' learning, 'necessary' learning, 'sufficient' learning and 'meaningful' learning. Table 2 describes each category or sub-set expressing a degree of learning.

The fuzzy set analysis

Three sub-sets form the input of the participation fuzzy inference system. The proposal aggregates partial participation in planning, design and implementation of improvements in one output set: global participation through a knowledge base of 19 IF–THEN rules. The inference considers the input functions and the left side of the rule (IF) or the premise to generate a new membership function (output) given the right of the rule (THEN) or the conclusion. For instance, if workers only 'get information' (a sub-set of participation, Table 1) in the three phases of the project (input conditions: planning, design and implementation) then global participation is low (output).

Two sub-sets form the input of learning fuzzy inference system. The proposal aggregates individual and group learning valuation in one output set: learning achieved through a knowledge base of 9 IF–THEN rules. For instance, if worker individual learning is 'weak' and group learning is 'necessary' as a partial result of the project (input conditions) then the learning achieved is weak (output). Both participation and learning fuzzy inference systems set up the predictive model. The fuzzy inference system was structured with triangular membership functions as shown in Figs. 1 and 2.

Validation test

The test of the proposal assessment (fuzzy inference system) for both participation and learning was based on a consultation with counselors accompanying improvement groups (considered experts). Experts provide conventional assessment based on their cumulative experience with data patterns to contrast with the evaluations made by workers regarding their own projects. They evaluate participation and learning separately based on calibration tables as shown in Tables 3 and 4.

The use of the "receiver operating characteristic" (ROC) curve is common in the evaluation of diagnostic systems (Franco & Vivo, 2007). There are experiences of ROC curve used to test fuzzy inference system (Esquivel et al., 2014). The predictive power is determined by calculating the area under the curve (AUC). This area takes values between 0.5 and 1. The area is calculated by the geometric method (trapezoidal) which coincides with the value of Wilcoxon statistic rank sum (W) used in the IBM SPSS algorithm under nonparametric conditions. Because available data is small N, only it is possible to test the efficiency of the system partially in the fuzzy scale ranging: 'high participation' sub-set and 'significant learning' sub-set.

In the test associated with the scale of participation, the area under the curve (0.931) shows that the fuzzy inference system for evaluating participation is appropriate to discriminate in the sub-set 'high participation' valuation range.

In the second test (the learning achieved scale), the area under the curve (0.917) allows the rejection of the null hypothesis in favor of the alternative hypothesis in which the fuzzy inference system for the assessment of learning is appropriate to discriminate in the sub-set 'significant learning' valuation range. In both tests the area under the curve is greater than 0.5, and the agreement between the experts and the system is 77.8% and 88.9% of the cases under consideration for participation and learning test, respectively.

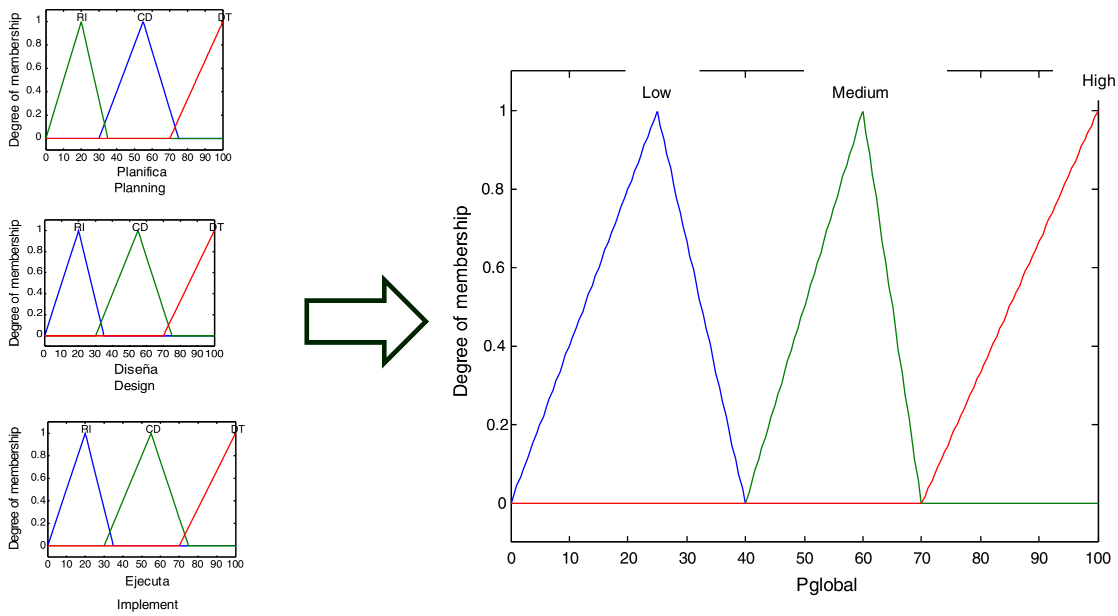

Fig. 1 – Fuzzy inference system: participation.

Findings and discussion

The fuzzy set scale approach and its configuration in a Mandami type inference system provides the possibility for participation and learning categories evaluation from the perspective of the individuals and group through informal improvement projects as learning activities. In this way, Santa and Nurcan (2016), identifies learning levels (person, team, organization) as generative mechanisms of the learning organization. The fuzzy inference system was structured with triangular membership functions as shown in Figs. 1 and 2.

Most measures in the macro-level of the organizational learning dimensions like 'participative decision making' are performed by variable oriented statistics (Chiva et al., 2007; Siadati et al., 2016). However, micro-level organizational learning happens in a complex verbal environment that requires new forms of measures. Ragin (2006) emphasizes that verbal theory is set theoretic in nature and must be evaluated in terms of statements about set relations. Participation and learning categories should be considered good candidates for this kind of measure. He suggests consistency and coverage indexes as useful measures to this evaluation. The consistency index is a descriptive measure of the degree to which a relationship between set occurs or the extent to which the evidence is consistent with the argument that there is a set relation (Ragin, 2006; Woodside, 2013).

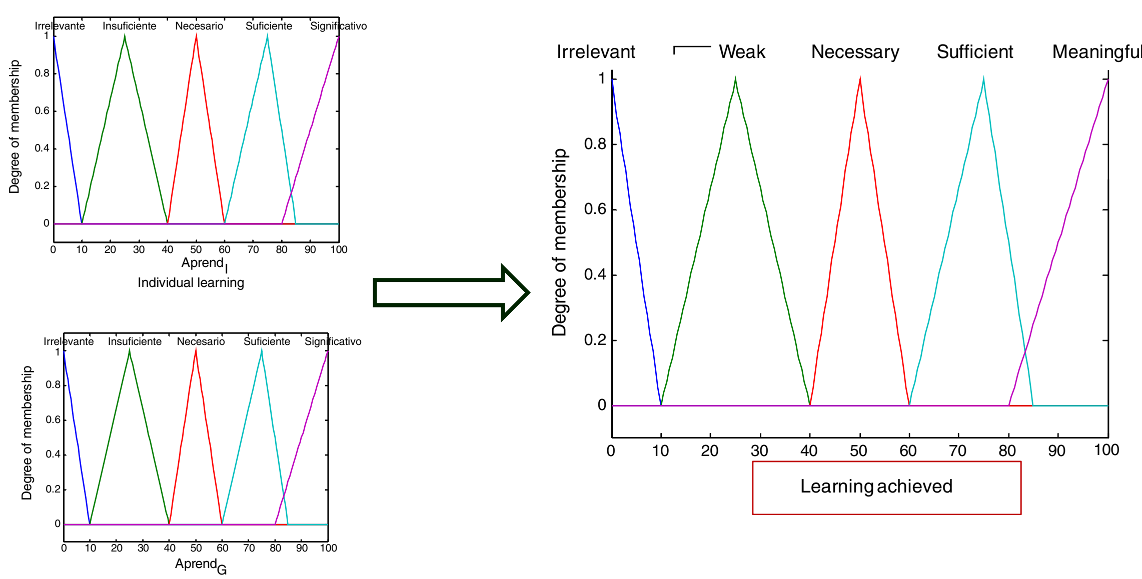

Fig. 2 – Fuzzy inference system: learning.

Table 3 – Participation (*P*) sub-sets: workers valuation (1), (2) and (3).

Project	Planning (1)	Design (2)	Implementing (3)	Mean P	Global *P* (inference system)
1	10	0	80	30.0	50.0
2	10	10	80	33.3	55.0
3	20	50	100	56.7	55.0
4	0	0	100	33.3	50.0
5	50	50	90	63.3	89.4
6	60	90	60	70.0	89.4
7	50	50	70	56.7	87.0
8	100	100	100	100.0	90.3
9	0	50	80	43.3	50.0
10	40	40	40	40.0	88.0
11	90	90	90	90.0	89.4
12	50	50	50	50.0	90.0
13	40	60	60	53.3	88.0
14	65	65	90	73.3	88.6
15	15	15	85	38.3	55.0
16	20	20	70	36.7	20.0
17	100	60	100	86.7	89.8
18	45	45	95	61.7	89.1
19	70	70	70	70.0	87.0
20	80	80	100	86.7	87.6
21	50	35	100	61.7	86.7
22	70	70	100	80.0	87.0
23	15	90	100	68.3	89.4

Source: Research data elicited with workers and analyzed with MATLAB® Fuzzy Logic Toolbox.

Table 4 – Learning (*L*) achieved sub-sets: workers valuation (1) and (2).

Project	Individual *L* (1)	Group *L* (2)	Mean *L*	Learning achieved (inference system)
1	80	80	80.0	73.1
2	70	50	60.0	62.2
3	100	100	100.0	93.7
4	80	60	70.0	73.1
5	90	90	90.0	92.5
6	90	90	90.0	92.5
7	90	90	90.0	92.5
8	100	100	100.0	93.7
9	70	60	65.0	73.2
10	100	90	95.0	93.7
11	100	90	95.0	93.7
12	70	40	55.0	73.2
13	90	85	87.5	92.5
14	90	90	90.0	93.7
15	70	40	55.0	73.2
16	60	50	55.0	50.0
17	90	90	90.0	92.5
18	95	85	90.0	93.3
19	90	85	87.5	92.5
20	100	80	90.0	93.7
21	90	85	87.5	92.5
22	90	90	90.0	92.5
23	98	85	91.5	93.6

Source: Research data elicited with workers and analyzed with MATLAB® Fuzzy Logic Toolbox.

In the cases under study, the calculation of the degree of consistency considers that the membership value of participation is X_i and the membership value of learning is Y_i. Under the premise of X_i values are less than or equal to the values of Y_i, consistency will be defined by:

$$\text{Consistency} \quad (X_i \leq Y_i) = \frac{\sum(\min(X_i, Y_i))}{\sum x_i}$$

For example in the evaluation of the improvement project case 12, the membership value of participation in planning, design and implementation (*P&D&I*) as a causal combination is $X_{12} = 0.80$ and the membership of learning achieved is $Y_{12} = 0.83$ then, $\min(X_i, Y_i) = 0.80$. The overall evaluation shows 17 out of the 23 cases consistent. Table 5 reports all cases.

The membership value for all cases under consideration and set combinations allows the exploration of

Table 5 – Participation (*P&D&I*) and learning (*L*). Causal combination.

	X_i = P&D&I	Y_i = L	Consistencymin(X_i, Y_i)	Coverage min(X_i, Y_i) exclusions
1	0.00	0.83	0.00	0.00
2	0.34	0.11	0.11	
3	0.80	0.69	0.69	
4	0.00	0.83	0.00	0.00
5	0.67	0.63	0.63	
6	0.67	0.63	0.63	
7	0.25	0.63	0.25	0.25
8	1.00	0.69	0.69	
9	0.00	0.83	0.00	0.00
10	0.40	0.69	0.40	0.40
11	0.67	0.69	0.67	0.67
12	0.80	0.83	0.80	0.80
13	0.40	0.63	0.40	0.40
14	0.50	0.69	0.50	0.50
15	0.51	0.83	0.51	0.51
16	0.25	1.00	0.25	0.25
17	0.75	0.62	0.62	
18	0.60	0.67	0.60	0.60
19	0.25	0.63	0.25	0.25
20	0.34	0.69	0.34	0.34
21	0.20	0.63	0.20	0.20
22	0.25	0.62	0.25	0.25
23	0.67	0.68	0.67	0.67
$\sum$	10.32	15.70	9.46	6.09

Source: Research data using MATLAB® Fuzzy Logic Toolbox and Excel®

sub-set relations in terms of necessity and sufficiency. The participatory context conditions under study fix the causal combination of research interest: the combination of the three partial participation sub-set (planning, design and implementing) with the expected outcome (learning achieved), and the simple sub-set relation between global participation and the outcome.

Learning achieved may result from several different combinations of participatory conditions (e.g., planning and design, planning and implementation, design and implementation) with each combination sufficient but not necessary for the outcome. But, workers participation in technology context and knowledge sharing demand the convergence of the three participatory conditions as a whole system (planning (*P*), design (*D*) and implementation (*I*)).

The first step is to examine participatory conditions whose configurations, before applying the fuzzy predictive model, can be considered subsets of the outcome (learning achieved). The consistency index is 0.918 and indicates that causal configurations (participation in planning, designing and implementing the improvement project) are sufficient condition for the outcome (the learning achieved). Fig. 3 shows this relation. The tool fs/QCA 2.0 (fuzzy set Qualitative Comparative Analysis 2.0) developed by Ragin, Kriss, and Sean (2006) supports the graphical analysis.

The analysis of consistency for the simple relation between global participation (as a result of the fuzzy predictive model) and learning achieved follows Ragin's approach (2006). The consistency in the fuzzy subset relation is considered by demonstrating that membership scores in participation are consistently less than or equal to membership scores in the achieved learning subset. For example, in the evaluation of the

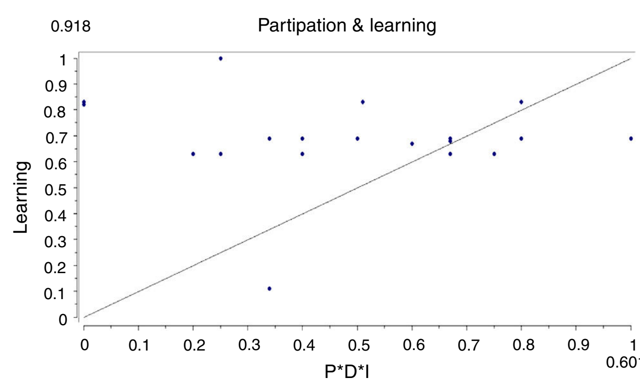

Fig. 3 – Participatory sub-sets conditions and learning relationship.

same improvement project case 12 from Table 6, the membership value of global participation is $X_{12} = 0.64$ and the membership of learning achieved is $Y_{12} = 0.83$ then, $\min(X_i, Y_i) = 0.64$. The overall evaluation shows 19 out of the 23 cases consistent.

Global participation (causal condition) constitutes a subset of achieved learning (outcome), a sufficient but not necessary condition for the outcome. Some cases in this relation sustain the asymmetrical idea pointed by Ragin (2006) and Woodside (2013). This subset relation is highly consistent (0.920) from a set-theoretic viewpoint, providing support for the statement 'participatory projects enable meaningful learning'.

Both, the analysis of the consistency measure (0.918) using causal configurations (Fig. 3) and the consistency measure (0.920) of global participatory as a single causal condition

Table 6 – Participation (P) and learning (L). Simple global relationship.

	$X_i = P$	$Y_i = L$	Consistencymin(X_i, Y_i)	Coverage min(X_i, Y_i) exclusions
1	0.66	0.83	0.66	0.66
2	1.00	0.11	0.11	
3	1.00	0.69	0.69	
4	0.66	0.83	0.66	0.66
5	0.62	0.63	0.62	0.62
6	0.62	0.63	0.62	0.62
7	0.54	0.63	0.54	0.54
8	0.65	0.69	0.65	0.65
9	0.66	0.83	0.66	0.66
10	0.57	0.69	0.57	0.57
11	0.62	0.69	0.62	0.62
12	0.64	0.83	0.64	0.64
13	0.57	0.63	0.57	0.57
14	0.59	0.69	0.59	0.59
15	0.66	0.83	0.66	
16	1.00	1.00	1.00	1.00
17	0.63	0.62	0.62	
18	0.61	0.67	0.61	0.61
19	0.54	0.63	0.54	0.54
20	0.56	0.69	0.56	0.56
21	0.53	0.63	0.53	0.53
22	0.54	0.62	0.54	0.54
23	0.62	0.68	0.62	0.62
$\sum$	15.11	15.70	13.89	10.50

Source: Research data using MATLAB® Fuzzy Logic Toolbox and Excel®.

(Fig. 4) are similar and show strong signs of consistency, near the unit. The main diagonal graphic or bisector line separates consistent cases from inconsistent ones. The points on the bisector line and above represent cases consistent with the argument that participation is a subset of learning. The points below the bisector line represent an inconsistency with respect to the relationship of participation as a subset of learning.

Another index is coverage (Ragin, 2000, 2006; Woodside, 2013). Coverage represents the proportion of cases that are covered under the assumption of subset relation considered (participation contributes to the learning achieved). Authors emphasize the need to prove consistency before proceed to the calculation of coverage. That is, the coverage will be considered if and only if there are signs of consistency. The calculation of the coverage excludes from numerator all cases that fall outside of the consistency test (below the main diagonal in Figs. 3 and 4).

$$\text{Coverage} \quad (X_i \leq Y_i) = \frac{\sum(\min(X_i, Y_i))}{\sum Y_i}$$

The analysis of coverage result of 0.60 (participation causal configurations) and 0.88 (global participation), respectively indicates that the cases in the study partially explain the outcome, learning achieved, which is due to the participation in the different stages of the improvement project as learning activities and require another socio technical conditions (culture, formal education strategies, decision making policies, power relations) at micro-level organization (Nonaka & Toyama, 2003; Nonaka & Von Krogh, 2009; Siadati et al., 2016).

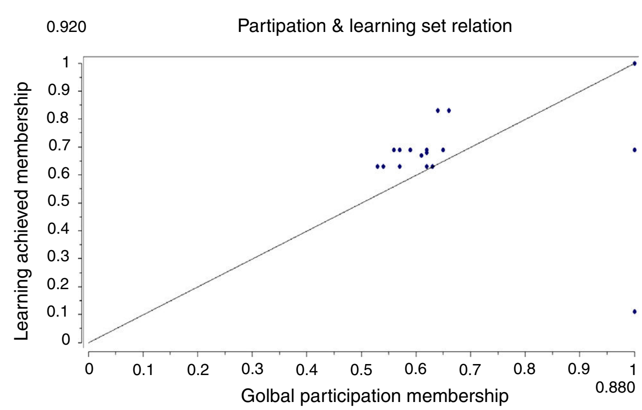

Fig. 4 – Global participation and learning achieved relationship.

Conclusions

The findings contribute to show a way to value participation and learning as fuzzy sets instead of variables. This approach provides the basis to value the degree of consensus between individuals of a group considering how participatory the experience is. In addition, the approach should be a tool to value the degree of learning related to collective knowledge sharing in an international technology transfer process which is a frequently activity in Venezuelan metallurgical industry.

Participation as a part of learning causal explanation is consistent with the evidence systematized by workers from their learning experiences (workers university initiative) identified in the areas of this research. In short, the relationship of fuzzy sub-set is shown as the membership values of global participation are consistently lower than the values of the outcome (learning). That is sufficient to establish a simple relationship between participation (causal condition) and the aggregated learning achieved (outcome). The observed asymmetry is associated with cases not explained by this relationship whose behavior can be linked to another set of conditions (Argyris, 1999; Lahera, 2004; Vieta, 2014).

Fuzzy sets approach offers the opportunity to transcend the conventional way of measuring social statement that have an impact on policy decisions. The fuzzy set scale approach is a useful way of assessing set theoretical relations. The calibration of set membership with criteria that come from stakeholders in a learning organizational context take into account their experience, their point of view and their influence in some policies beyond their workplaces. New generative mechanisms (Santa & Nurcan, 2016) require the consideration of workers participatory initiatives for development a learning organization.

Limitations and future lines of research

The limit of this research is related to informal activities that workers perform in their workplace. The main difficulty is that empirical data comes from voluntary workers' groups for technical improvements without much time to participate in every stage of the research. Participation in technology relates multiple sub-sets, not only planning, design and implementing. In some projects, workers participate in decision making about equipment acquisition or machine automation and it was not considered.

Research opportunities are oriented to the need of taking into account the relative importance of participation in each one of its components (participation in the planning, design and implementation) or the corresponding fuzzy subsets.

The fuzzy scales need to be refined: in the calibration phase emerges a great debate about how close/far away the sub-sets 'sufficient learning' and 'meaningful learning' are. Stakeholders argue that "when learning is increasing they perceive (value) that the changes are more difficult to differentiate" (blurred between scales).

In agreement with Mendel and Korjani (2012), it is necessary in depth studies about the problem of obtaining membership functions when a causal condition is described by more than two terms. For example, the inclusion of two or three (or more) terms like in the present study. The impact of using a triangular function to express continuous set membership on fsQCA needs to be studied too.

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