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FOUR QUESTIONS ON COMPLEXITY AND LEARNING

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ABSTRACT

Increasing interaction (in numbers, patterns and uncertain intensity) in innovation processes point at new and different methodologies of researching reality including complexity views of modern production. In post-modern era, where (informational) networks are evolving, learning can not be understood through the lens of organization, but through learning individuals. Such approach can be attained by Interaction analysis which gives typical pattern of connections among attributes describing phenomena. Interaction analysis is the first step to functional modeling as a method of multidimensional optimization for chosen criteria. Functional modeling satisfies processing approach which treats surroundings as complex, uncertain, full of changes and emergent phenomenon. Empirical analysis indicates that companies in Slovenia in the year 2003 are not characterized with category of Learning organization.

KEY WORDS

interactions, innovation process, learning organization, view of complexity, uncertainty

CLASSIFICATION

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WHY QUESTION OF COMPLEXITY IN PRODUCTION?

"Straight stream" economic science (where neoclassical economy is entirely in the focus) explore reality on presumptions that market and production are at all times shaped in the same complexity, so there is no need to expose complexity as the objective factor in understanding the laws regulating economic life. That practically means that exploring tools of 19th century world economic reality are the same as the ones of 21st century.

The heterodoxy economy is not satisfied with such presumption and takes into consideration specific and limiting characteristics of complexity. It is known that notions of systems and complexity have been developed as a response to dissatisfaction with the science that dominated in the early 1900s [1]. Science commonly referred to as »Newtonian« includes linearity, predictability, control and access to perfect knowledge.

An actual understanding of complex system is one where inferences require the insight of different disciplines operating at different scales, where there is irreducible uncertainty; and, where there are multiple phenomena like future states, predictability and perfect knowledge unattainable. Opposite to the Newtonian world a view of the emergence of post-modernism in the mid–1990s in the literature and social criticism had started to influence also other fields of the science. The new science called as Science of Complexity or Post-normal Science had started to reflex a new epistemological and ontological perception as follows:

- the core concept of the science of complexity is one in which the state of the phenomenon is uncertain,
- the science of complexity is with hypothesis of uncertainty avoiding complete information that why an epistemological variant of irreducible uncertainty, bounded rationality has to be practiced in theories and empirical models,
- sufficiently complex systems demonstrate behavior which could not be predicted as based on the separate behaviors of the system components, but can be only explained in terms of the component properties; consequently, complexity is irreducible and phenomena can not be simplified without losing their essential nature,
- irreducible uncertainty and bounded rationality certify the role of subject with different, equally valid, imperfect view of some portions of the phenomenon.

The economic theory representing views of complexities – evolving complex systems ("Santa Fe approach" [2, p. 3]) is answering the question what is complexity perspective in economics. The concept is based on the critique of conceptions of the "equilibrium" and "dynamic systems" approaches. In the first, the problem of interest is to derive, from the rational choices of individual optimizers, aggregate level of "states of economy" that satisfy some aggregate level consistency condition (market clearing, Nash equilibrium), and to examine the properties of these aggregate level states. The equilibrium approach does not describe the mechanism whereby the state of the economy changes over time and also how equilibrium comes into being. The second approach represents the states of economy by a set of variables. A system of difference equations or differential equations describes how these variables change over time and the problem is to examine resulting trajectories, mapped over the state space. The dynamical system approach generally fails to accommodate the distinction between agent and aggregate levels. Obscuring "representative agent", the emergence of new kinds of relevant state variables, even less new entities, new patterns, new structures, is not possible. The complexities of process and emergence approach are based on six features of the economy as phenomena which are called "adaptive nonlinear networks" [2, pp. 3-4]:

- the mechanism of the economy is based on the interaction of many dispersed, possibly heterogeneous agents acting in parallel,
- no global entity controls interactions,
- the economy has many levels of organization and interaction,
- agents continually accumulate experience and constantly adapt themselves,
- perpetual novelty is created by new markets, new technologies, new behaviors and new institutions,
- improvements are ongoing and occur regularly, so economy operates far from any optimum or global equilibrium.

Consequence of learning in an economy is technological change which is in the focus of a study of an innovation process and is a motive power of modern economies. The study of the technological change addresses questions relating to: the sources and the direction of potential improvements, the selection of actual changes of all potential changes, the process of introduction of such changes and their impact [3, p. 2]. Acquired knowledge is absorbed in the whole innovation process and encompasses improvements of a researching process of a new product, production processes, material and their development and intermediate inputs in management methods, new organizational concepts and knowledge of marketing in the economic system. Innovation process constructed of a complex technology involves not only firms own research and development (R&D) activities, but also their capabilities of outside technology, consequently point of a view of the whole economy is of a crucial importance. Therefore useful products and processes result from a variety of sources and meet performance constraints along multiple dimensions. Codified knowledge is not a sufficient guide to practice, because assimilation of outside technology and prediction of the operating performance of complex technological artifacts is not assured automatically. That why firms most of the time spend on development activities and not only on activities of invention (researching activities). Beside importance of a tacit knowledge [4] accumulated through experience and on-the-job experimentation, social interactions and transfers are also of crucial importance for firm's innovation progress. These characteristics of technology and organization of the innovation process have a major implication for the conceptualization of characteristics of the measurement of a learning process attributes. First we have to understand not only research & development activities as a complement to the absorption of outside technology [5, p. 18] but also all other organizational information receiving from several organizational level of socially created innovation process. Second, relations among several social actors at different social levels are explanations for filtrations of competitive information and acceleration of a diffusion of general transferable information. Third, an inevitable consequence of the complexity of technology is its variety. Because technological knowledge emerges mainly from several firms' development and production activities it is more accurate to speak of technologies of a social production [5, p. 19]. From the point of view the current period research is concentrating more on developmental processes of unlocking and path creation within a national economy [6]. In such context micro-macro interactions at different levels, providing structural and developmental orientations, are important.

The important cognition is that increasing interaction (in numbers, patterns and uncertain intensity) in innovation processes point at new and different methodologies of researching reality including complexity views of modern production. So social production of technologies asks for complex point of view in the sense of existing uncertainty in predicting interactions among specified (but not fixed) characteristics of phenomena and evolution of phenomena as a whole itself.

IS LEARNING IN A PRODUCTION A QUESTION OF ORGANIZATION OR HUMAN ENTITY?

Literatures of learning organization takes for true that organizations[1] learn. Such conclusion is avoiding complexity context and is dangerous in global condition for long term production prosperity. Global capital exerts pressure on social production, politically excluding human rights in production and consumption and with that on the main source of growing knowledge. Behind global capital stands power of control over all resources that may evolve its growth. Consequence of such development is world inequality, misery and ecological changes which destroy what has been produced with the assistance of the capital if we mention only the most visible results.

We will use the multilevel theory to show alternative concept in understanding category of learning which limits asymmetrical capital development in the benefit of all stock-holders in a production and enable a more integrated understanding of phenomena in a modern way of production. Fundamental to the level perspective is the recognition that micro phenomena are embedded in macro context and that macro phenomena often emerge through the interaction and dynamics of lower-level constitutive elements. The macro perspective neglects the means by which individual behavior, perceptions, motivations affect and interactions give rise to higher-level phenomena. In contrast the micro perspective has been "guilty" of neglecting contextual factors that significantly constrain the effects of individuals [7, p. 7]. As authors wrote organizations do not behave; people do and we add so they can not learn. Another very important category in the multilevel theory is a construct – abstraction used to explain apparent phenomena. A construct may appear on different levels. In the context of learning in organization we are describing the influence an individual learning exerts in unit knowledge. Such learning can not be captured by category of learning organization. It is more collective knowledge gained by interactions among organization members. It is necessary to make important distinction. Collective phenomena may emerge in different ways under different contextual constraints and pattern of interaction[2] [7, p. 59]. Collective knowledge may be conceptualized as the sum of individual knowledge. But alternatively knowledge may be conceptualized as configural spirals where some individual's knowledge is more useful than other knowledge. Organizational learning as category can be identified only by isomorphic models, where all knowledge converges to the same point. Interactions are stable, low dispersed and uniform. In such a case we talk about emergent process of composition. Organizational learning (better organizational knowledge – as a structural point of view) is sum of individual knowledge.

Learning as a process and results in the sense of emergent characteristic explained with patterns of interaction allow that even small changes in individual knowledge and interactions yield to big nonlinear changes. Patterns as representation of emergence show discontinuity come out from personal diversity. Such consideration is able to capture the rich complexity of emergence and importance of adaptive team networks. Organization is not any more once for all the time accepted linkage among people (supported by legal regulation of the states). Inversely networks are flexible, irregular, high dispersed and no uniform, supported by knowledge of multiple solutions in decisions. Category of organizational learning does not cover the essential processing of networks. Political theories treating society as a system [8, pp. 7-10] are very often object of a critique as leading in reification, what means that theories ascribe actor characteristic to systems (instead of an action of actors they are ascribing an action to systems). Complication involving collective actor arise from misunderstanding the category "emergence" [8, p. 8] when the same is not connected with multilevel structure of society. Political theories (especially Sibeon's one) do not see that the transformational process

emergent result is located on the level of an organization, although organizational decision process is located on the level of actors. Actor and emergent results are connected with cross level transformational mechanism (in Bhaskar's theory). In multilevel theory position of actor is specified and not relativized like in Makarovič's theory where "it seems that organization is an actor who takes a decision and performs concrete decisions" [8, p. 9].

Multilevel theory says that all performances in organizations, regardless of the level of analysis, must ultimately be a function of individual-level behavior. Organizational behavior and corporate performance are really still a function of coordinated efforts by individuals [7, p. 131]. The term "organizational" accustom on the structure which in the accepted concept of appeared flexible networks freeze up "organizational relations" not allowing emergence of a new one. Adaptive networks are not just aggregates of individuals. Individuals always exist as a basis for all teams and other types of networks. Networks go beyond the individual where individuals learn interactive with other individuals how to integrate individual-level and team-level goals.

Networks top-down limit participants with the context of the existence of the whole network. In human resource literature such context is denoted as organizational climate comprehended as a shared or summary perception that people attach to particular features of the work settings. Organizational climate is distinguished from psychological climate, which is based on individuals' perceptions of possibilities how problems exist and how can be solved. If theory of learning organizations accedes to learning from the aspect of structure, its context presupposes system with determinated number and pattern of individuals (or entities). Multilevel theory solve the problem of learning via open system, what means that number and configuration of relations are no more fixed through abstraction, but allow new relations in time and new players in adaptive network. Networks are alive: so part of them are dieing and some are new born – this is an idea how to imagine category of process. The aim of this researching paper is to expose complex characteristic of learning and measurement possibilities.

Last point of view is to look on complex learning from the global point. If we connect attribute globally to phenomena capital than we can see that noun learning (organizational learning specifically) is by its substance closed system in the sense, that learning must be organized strictly to support profit maximization and no criteria of social production does exists. Capital and category of capitalist organization are complementary parts of category exploitation. Exploitation exists on closed organization where every not defined relation cause uncertainty in a way that when opened appear probability that some resources will be lost. Social context of capitalist production must minimize all risks. In that way inherent capital autonomy in its global function exclude learning components, which are socially acceptable, but entropic from the point of the individual capital. In post-modern era, where (informational) networks are evolving, learning can not be understand through the lens of organization, but through learning individuals who are not necessarily included in defined organization[3] but are for sure included in appearing adaptive networks.

WHICH IS CONSISTENT COMPLEX CHARACTERISTIC OF A LEARNING PROCESS ATTRIBUTES AND ABOUT ITS MEASUREMENT?

The first step would be working definition of emergency as one of the most important characteristic of complexity at all. Mitleton-Kelly [9, p. 19] defines that emergent properties, qualities, patterns, or structures, arise from interaction of individual elements; they are greater than sum of the parts and may be difficult to predict by studying the individual elements: Emergence is the process that create new order together with self organization. Organizational learning can be properly understood only in the context of emergence.

Knowledge and innovative ideas could be described as an emergent property in the sense that it arises from interaction of individuals, and is not just the sum of existing ideas, but could be something quite new and possibly unexpected [9, p. 21]. Articulated and implicated ideas form part of the history of each individual and the part of the shared history of the network as a whole. Only in this way network (organization) learn, as new ideas and new knowledge can be built upon to generate further new ideas and knowledge. Learning leads the whole organization to new behaviors and organization is adapted and evolved. New knowledge needs to be shared among individuals to generate further new learning and knowledge. If organizations have been understand as complex evolving systems, co-evolving within a social ecosystem, than organizations and social ecosystem can be viewed as self-organizing human information-processing and communications systems [10, p. 6]. The same author understands social systems as a dissipative structure [10, p. 7]. At the level of the individual perception, cognition and learning are activities which reduce apparent chaos to manageable proportions based on identifying apparent regularities. Cognition allows us to "fix" such regularities (symmetries, patterns). Repetition of the process and our observations allow us to distinguish a category (by van der Leeuw pattern of patterns) defined by the nature of dimensions involved and the ways they intersect. New pattern is in a substance a new point of view, providing a new perspective and new solutions of further problems. On the base of a new interpretation of phenomena – new cognitive categories can be formed interpreting the first. Such learning process is continuous, modifying meanings from interactions among perceptions.

Following the theory of complexity social systems are opened in exchange matter, energy and information with their environment [10, p. 10]. The exchange of matter and energy satisfies the condition of decreasing the uncertainty in the system when system is closed (the condition of the complete competition). When exchange of knowledge and information is included social systems are complex by its substance and opened to environment. Increase in the quantity of information among individuals leads to request in increase in participation and coherence [10, p. 10] – what means increasing the degree of organization and dissipating entropy. Social systems insisting in historical social structures may consist only on negative feedbacks, exporting its inherent tendency to system environment. Change to higher social coherence is attainable only with positive feedbacks which assure that between innovation and dissipation is sufficient time lag. If social structures, as in the case of global capital, are not evolving sufficiently, noise blocks necessary integration and leads to chaos. That why importance of complex characteristic of a learning process is present.

In accordance with Penrose's theory of resources learning organization is composed by not determined number of attributes, of which only determined number is important. Naïve presumption is that important attributes are independent. Data of attributes which are scarce or infrequent are especially not robust. Measuring methods used for exploring emergent properties on the filed of learning are of such characteristic. Their myopia is especially evident in the case of concept of excluding "or" – disjunction (in the exclusive sense): $C = X \vee (X, Y)$, where C is Boolean class and X, Y its attributes[4]. If we examine only attribute X, than C value is not evident. The reason is that the relation among X and C are crucially dependent of Y. For $Y = 0$, $C = X$, for $Y = 1$, $C \neq X$. The same misses also attribute. Only than X and Y together describe C. The theory says that exist positive and negative interaction among X and Y with regard to C. In the information theory information content is measured with entropy. If phenomena expresses primary metrics with random variable X and are N possible values (events) of that variable in the chosen context can be its differential distribution of possibility x_i, i = 1, …, N used for calculation appertained statistical parameters with uncertainty, for which measure can be used Shannon's type as the most simple probability entropy:

$$H(X) = -\sum_{i=1}^{i=N} p(X) \log_2 p(X) \tag{1}$$

where p is the probability of the phenomena. In the case of two random variables X in Y, which appertain to primary metrics of two different phenomena, the possibility that both characteristic are (probabilistically) independent is generally excluded; what means exclusion of the existence of equitation $p(X, Y) = p(X) \cdot p(Y)$. If random variables X and Y are distributed discreetly first with N and second with M events, exists maximally MN common events. Mutual entropy can be written as:

$$H(XY) = -\sum_{i=1}^{i=N} \sum_{j=1}^{j=M} p(XY) \log_2 p(XY) . \tag{2}$$

XY is a new probabilistic variable which sum of events is Cartesian product of sums of events which X and Y appertain to separately. Mutual entropy $H(XY)$ is minor or at the most equal to the sum of separate entropies $H(X) + H(Y)$. Minor is when variables are dependent. Dependency can be measured with mutual information or *information contribution*:

$$I(X) + H(Y) - H(X, Y). \tag{3}$$

Generalization of the concept of mutual information on more variables in a measured quantity is termed interaction information or *interaction contribution*. For the case of variables X, Y and C can be written:

$$I(X; Y; C) = I(XY; C) + I(X; C) - I(Y; C). \tag{4}$$

Interaction contribution can be positive or negative. Positive contribution expresses positive interactions or synergy, negative contribution inversely: negative interaction or dependency (redundancy originates in same information given by both variables).

Interaction among attributes gives their correlation – typical pattern of connections among attributes describing phenomena. Interaction analysis is the first step to functional modeling as a method of multidimensional optimization for chosen criteria (class C) respecting optimal direction of changes in the form of elasticity of chosen criteria regarding individual changes in attributes. Functional modeling satisfies processing approach which treats surroundings as complex, uncertain, full of changes and emergent phenomenon. Functional modeling is solving dilemmas of global changes in developing own knowledge, acquiring knowledge of others; assure forming of expectations and propensity to decisions which have higher probabilities to be realized.

HOW TO COMMENT SOME RESULTS OF "LEARNING ORGANIZATION" THROUGH THE LENS OF COMPLEXITY, LEARNING AND GLOBALIZATION?

Approaching problems of complexity and learning and its measurement we explore data from questionnaire for learning organizations in the project [11]. The path to learning organization collected in 2003 by Institute of learning organization, Ljubljana, Slovenia.

We apply interactive analysis which enables insight in relations among attributes. But numerical conception often does not associate relevant patterns in data which generalize understanding of the phenomena. Thus we may represent data as in statistical and mathematical visualization. In our research we used dendrograms and interaction graphs to present relations

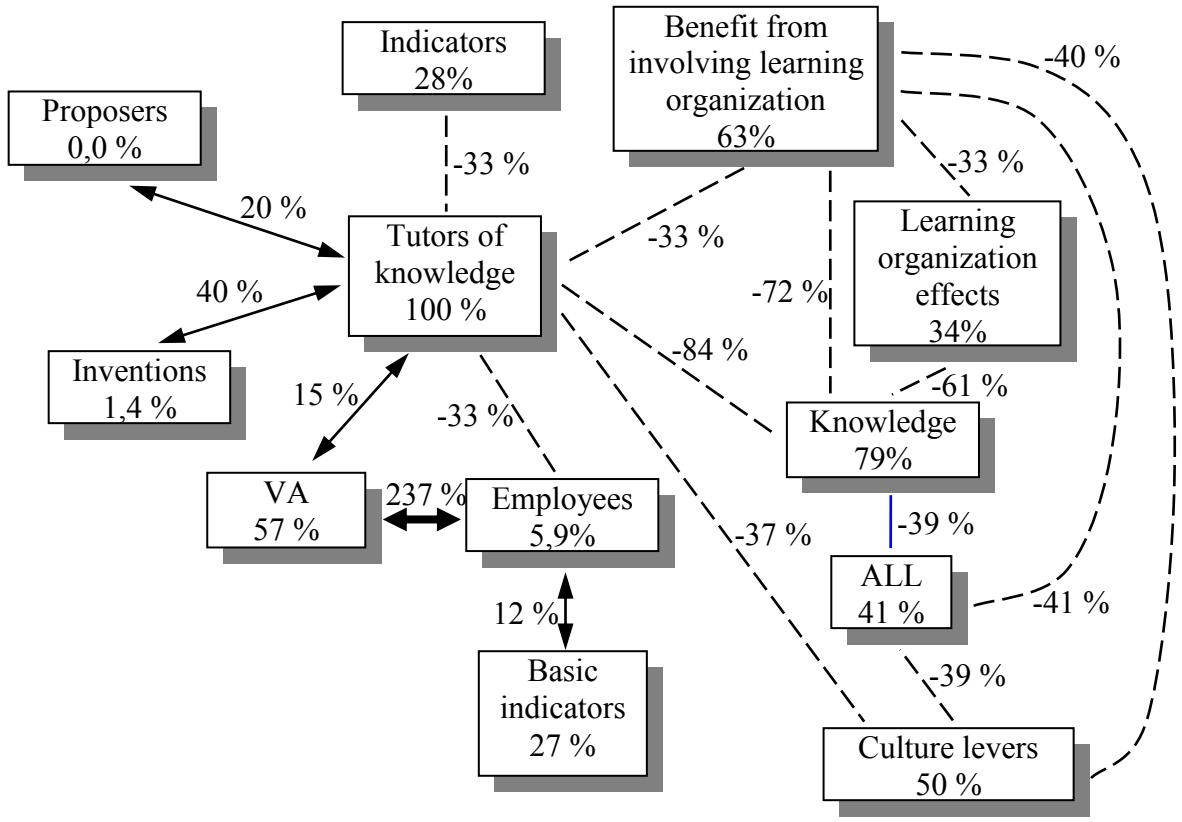

Figure 1. Interaction graph for linear, non-weighted model of attributes of the Learning organization in the year 2003 in Slovenia. Calculation from: *The path to Learning organization*, collected 2003, Institute of Learning organization, Ljubljana, Slovenia. Full (dashed) lines denote positive (negative) interactions. Numbers in squares are self-information of attributes.

Attributes are denoted as follows: *Learning organization effects* – Cite three most pozitive effects as a consequence of introduction of the concept of the Learning organization; *Indicators* – Cite three indicators which is used in firm to monitor effects of investments in the knowledge; *Benefit from involving learning org.* – Concept of the Learning organization has effected positively on efficiency of the firm; *Tutors of knowledge* – For strategic spheres of activity we named tutors of knowledge (How much per 100 employees); *Proposers* – percentage of employees which gave one useful proposal in the last year; *Inventions* – Number of registrated useful proposals and inventions per employee in the last year; *VA* – Value added; *Basic indicators* – Basic indicators in total; *Knowledge* – Acquiring and managing with a knowledge (in total); *Employees* – Number of employees; *Culture levers* – Levers of development of the organizational culture of the Learning organization; and *All* – All indicators.

among variables or attributes. Figure 1 gives one example of interaction graph for linear, not-weighted model of attributes of the learning organization. In Figure 1, let us concentrate on positive interactions: Attribute *Tutors of knowledge* suppresses alone 100 % of the uncertainty, *VA* (value added) 57%, *Basic indicators* suppress 27 % of the uncertainty, attributes *Tutors of knowledge* and *Proposers* additionally 20 %, *Tutors of knowledge* and *Inventions* 40 %, *Tutors of knowledge* and *Value Added* 15 % additionally. Correlation between *Value Added* and *Employees* is 237 % and means only that interaction between attributes is more informative than most informative attribute.

Negative interactions in Figure 1: Extremely great are percentages of a suppressing uncertainty in the case of attributes of *Learning organization effects* – 34 %, *Benefit from involving learning organization* 63 %, *Indicators* 28 %, *Knowledge* 79 %, *Culture levers*

50 % and *All* – 41 %. Mutual information among mentioned attributes is great because different pairs of attributes assure between 84 % (as in case of *Tutors of knowledge* and *Knowledge*) and 33 % (among four pairs).

Presumptions of the definitional[5] process of creating knowledge are given in the three following subsections.

IN THE SPHERE OF CREATING KNOWLEDGE WE TESTED STATEMENTS

Companies are knowledge creating entities because knowledge and capabilities to create and use a knowledge, the most important source of sustainable advantages on market competition [12, p. 1].

Learning as a company characteristic affect value added. We will confirm this statement through measuring the connection among attributes Employes who plan with managers their own learning and development and Value Added from the period.

IN THE SPHERE OF INTEGRATION OF KNOWLEDGE

Extent of a company [3, p. 35; 13. p. 85] is in correlation with the attribute that Companies sustain essential knowledge in collection of all knowledge, and the attributes that Changes in companies are planned.

Smaller firms are likely more opened to adopt a new knowledge [14, p. 71]. We expect that companies are aware of their knowledge and that they economize with it. We examine correlation between attributes Intensive exchange of knowledge and Value Added.

IN THE SPHERE OF MEDIATION OF KNOWLEDGE

Absorption capacity is defined as capability to learn from external sources. For this reason company as a complex system has to develop systems for receiving and mediation external decision information [15, p. 189, p. 192]. We examine if attributes Spreading information from bottom to the top and Introduction concept learning organization has positive effects on Value Added.

New theory or Theory of endogenous growth confronts a number of individual activities in company with condition of work, which create these activities. Theory is focusing on question: How collective learning and knowledge effect on an individual production process [16, p. 378]? Is possible that including extensive circle of employed on solving to their decision problems improve business effectiveness (and business effectiveness of an individual production processes)? For this reason we examine if attribute Employed regularly accept information of achieved aims and financial results of operations correlated with Value Added.

CLARIFICATIONS OF EMPIRICAL PROCESS OF CREATING KNOWLEDGE

In the sphere of **creating knowledge** in the weighted model of selected liner connected attributes growth the importance of the knowledge of modern organizational concepts (correlation with *Value Added* is $\rho = 0{,}81$). The analysis shows interaction contribution of attributes Decentralization of planning, Integration of activities, production concept and standard program.

In the sphere of **integration of knowledge** we have not found confirmation of the role of educational structure and connection with *Value Added*. Presumption that attribute Final product is correlated with attribute Standardization is verified in interaction in nonlinear graphs. In non-weighted model mutual information between attribute Final product and attribute Standardized program are weakly correlated ($\rho = 0{,}055$).

In the sphere of **mediation of knowledge** we couldn't find correlation among attributes Decentralization planning function, processing and control and Value Added. In interaction graphs of non-linear models is attribute Decentralization planning function positively interactive with attribute Integration activities.

CONCLUSIONS

Empirical analysis indicates that companies in Slovenia for the year 2003 are not characterized with category of Learning organization. Types of organization's are important for company's evolution of knowledge what expose the importance of the attribute Tutor of knowledge. Absorption capability is not strengthen satisfactory in complex organization of production because decision component is missing. We can conclude that developmental processes are more oriented in capital globalization than in the direction of self-organizing society of learning citizens.

REMARKS

[1]The term must be translated as "a firm", because the term organization has several other meanings in organizational science.

[2]Emergence is often equfinal rather than universal in form.

[3]In mentioned sense.

[4]Interaction analysis is described in [17-20].

[5]By Hierarchy Theory defines that *definitional entities* are postulated before a measurement is made. When a measurement is made a new class of entities arrives – *empirical entities* [21].

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ČETIRI PITANJA O KOMPLEKSNOSTI I UČENJU

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SAŽETAK

Rastuća međudjelovanja (po broju, vrstama i procijenjenom intenzitetu) u inovacijskim procesima traže nove i različite metodologije istraživanja stvarnosti, uključujući i pogled na modernu proizvodnju sa stajališta kompleksnosti. U postmodernom razdoblju u kojemu (informacijske) mreže evoluiraju, učenje ne može biti objašnjeno iz perspektive organizacije, nego iz perspektive učećih pojedinaca. Takav pristup može biti postignut Analizom međudjelovanja koja daje uobičajene vrste veza između atributa kojima se opisuju pojave. Analiza međudjelovanja je prvi korak prema funkcionalnom modeliranju kao metodi višedimenzijskog optimiranja za dane kriterije. Funkcionalno modeliranje zadovoljava procesni pristup koji uključuje okoline kao kompleksne i neodređene, emergentne pojave, pune promjena. Empirijska analiza ukazuje kako tvrtke u Sloveniji u 2003. godini ne mogu biti karakterizirane kategorijom Učećih rganizacija.

KLJUČNE RIJEČI

međudjelovanja, inovacija, učeća organizacija, stajalište kompleksnosti, nesigurnost