SYNTHETIC THINKING IN (SPORTS) SCIENCE: THE SELF-ORGANIZATION OF THE SCIENTIFIC LANGUAGE

UDC796:001.8(05):
(Original scientific paper)

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Abstract

We present a phenomenological model outline of self-organization in the scientific conceptual space with emphasis of the position of sport sciences. The obtained model has a rugged structure of basins of attraction and the learning dynamics is defined as a hopping of the learning system within the confined general basin of attraction. The paper examines how changes in the conceptual space change the structure and the dynamics of exploratory behaviour of learners. When concepts of higher explanatory generality are absent the system becomes fragmented in mutually weakly connected or disconnected basins of attraction which corresponds largely to the current state in science and humanities education. On the contrary, when such concepts are present, the height of the barriers significantly lowers and the system reconfigures itself into a landscape of connected basins of attraction offering a unification of apparently distant areas of knowledge. The general explanatory concepts play the role of 'catalysts' which lower the transition barriers between conceptual spaces of scientific fields. We further discuss how general explanatory concepts from the nonlinear dynamical systems theory and statistical physics can become tenets of a new educational program and teacher profile.

Key words: *science, sports science, education, synthetic thinking, conceptual self-organization, scientific language self-organization*

INTRODUCTION

Science is a cooperative social endeavor. Large groups of scientists explore and strive to explain the immense diversity of processes dwelling on different levels and time scales of substance organization. The explanations acquired are continuously shared within and among scientific communities through language which enables, among the other, emergence of new ideas and exploratory approaches. Sports science makes no exception to this rule. On the other hand, the diversity of phenomena constrains the scientific language of each discipline to form a specific vocabulary for naming and explaining the natural properties and processes as well as communicating the knowledge among scientists. The communication of the knowledge among sciences is a central topic of this paper. For example, would a cosmologist, cell biologist, sport scientist and a sociologist understand each other when explaining the basic processes within their fields. Not so much, one would say. Cosmologists speak about inflationary and electroweak epoch and space-time metrics, cell biologists about cell membranes, enzymes and ribosomes, sports scientists about triple vault coordination, kicking performance and double-passes and sociologists about group formation, cohesion and social attitudes.

Recently the diversity of phenomena and properties of the organized substance was ascribed to the existence of the so called "mesoscopic protectorates" (see e.g. Laughlin et al. 2000), i.e. emergent organization levels of substance whose key properties cannot be formally, i.e. mathematically, deduced from the laws that govern the behavior of the more microscopic components (for a detailed explanation on this see e.g. Mainwood, 2006). Hence, each level creates idiosyncratic and novel structures and properties which need a specific language for dealing with them. These languages, thus, use context dependent concepts for naming and explaining the process under scrutiny. This context dependence is essentially viewed as the major cause of the fragmented vocabulary among scientific disciplines. That is, while within specific scientific fields and subfields the knowledge communication goes easy being enabled by common vocabulary, it becomes less and less so between more distant disciplines.

In the past few decades, however, there is a growing success in explaining and modeling different levels of organized matter by common universal dynamical concepts. The search for minimum principles which explain maximum number of phenomena is a tacit motive in all sciences, at least their theoretical disciplines. On the top of that it has been proven as a very successful one both on theoretical as well as empirical levels. The onset of this trend may be located in Newton's works where he unified different phenomena such as, celestial mechanics, earthly tides and falling bodies into the law of universal gravity. Maxwell followed this trend in unifying the apparently distinct phenomena of electricity and magnetism into a unified electromagnetic theory. Einstein unified the notions of space, time, matter, energy and gravity into an even more general theory and started a program of unifying the fundamental forces of nature in a framework today known under the name of "The Grand Unification".

Aside of this type of unifying tendencies, but closely related to them, yet another type of unifying approach emerged at the start of the second half of the 20-th century with works in condensed matter physics (Landau,1969). This tendency is characterized by connecting different sciences through finding deep analogies among seemingly unconnected phenomena. Already at the start of 60-es a very fruitful link was established between condensed matter physics and elementary particle physics (e.g. Englert & Brout, 1964; Higgs, 1964) and non-equilibrium physics (Haken, 1964) and the successes of explanation of phase transitions in late 60-es and early 70-es (Kadanof, 1966; Wilson,1975) was paralleled by similar progress in non-equilibrium chemistry (Glansdorff & Prigogine, 1971) and shortly after in the nonlinear dynamics (e.g. Cvitanović et al, 1984). Already at the end of 70es and in early 80-es first works appeared explaining the animal and human movement organization (Kelso et al., 1979) relevant to sports sciences as well as sociology of groups (Isnard & Zeeman, 1974) using similar concepts as those in the aforementioned areas of science. The advent of neural networks and the protein folding models provided a strong boost to the spreading of these ideas in general biology (Hopfield, 1982; Wolynes et al., 1995, Pollak & Chin, 2008). This wave of applying general explanatory concepts in diverse fields of research is growing in an ever increasing rate as if it is guided by a positive feedback loop, suggestive of the spontaneous self-organizing transition phenomena.

Hence, the main aim of the research was to examine the changes within the linguistic, i.e. conceptual, landscape profile of scientific fields under the absence and presence of general explanatory principles coming from the nonlinear dynamic systems theory (NDST) and statistical physics (SP) (NDST-SP onwards) in diverse scientific fields. Specifically, we aimed at modeling of the conceptual space of science as a self-organizing system emphasizing sports sciences position within it. Due to the limited space, on the next few pages will be presented the preliminary outline of the results of the investigation undertaken to reveal the change of scientific language within the past several decades. Particularly, we aim to show hallmarks of scientific conceptual self-organization within the language space as represented by a dimension reduction and information compression effects.

METHOD

Sampling of concepts and literature

Characteristic concepts from 10, classically widely separated scientific fields, such as: elementary particle physics, cosmology, molecular physics, chemical reactions, cell biology, neurobiology, psychological processes, motor behavior, collective sports research and sociology of groups; were treated as linguistic degrees of freedom. In the first phase, for each scientific discipline 35 basic explanatory and empirical concepts were used. Concepts were extracted from contemporary university and high school textbooks. The concepts which defined the chapters, headings and subheadings were first extracted and then the rest of the most frequent generic concepts within each part of textbooks. Experimental apparatus, data extraction concepts as well as pure mathematico-technical terms were not taken into account. The following general explanatory concepts coming from NDST-SP were used: self-organization (self-assembly or soft-assembly), collective modes (order parameter, collective coordinate or variable, reaction coordinate), control parameter or variable, phase transition, bifurcation, symmetry-symmetry breaking, stability, instability (loss of stability), metastability, criticality (critical point or manifold), gradients, scalar field, vector field, attractor, repeller, entropy-information, network.

The second phase of the data collection consisted of Internet search of published scientific papers from the previously mentioned scientific fields archived in relevant databases, such as Scopus (Science Direct), Web of Science, Google Scholar, ArXiv. The sample papers from each of these fields were taken from pertinent impact factor journals. In total 1276 papers were collected over a period of one year (May 2011 – April 2012). A co-word analysis was performed, that is, combined expressions consisting of previously extracted scientific concepts and concepts from NDST and SP were searched for each scientific discipline. This procedure enabled us to detect the presence or absence of NDST-SP explanatory concepts in each of the scientific disciplines and, among the other, to detect roughly the periods when such combinations first emerged in the scientific literature.

Methods of analysis

Each conceptual space of scientific fields was represented by a binary vector. The value of 1 was assigned to the concepts that existed in the scientific discipline and the value of 0 otherwise. Salton's cosine similarities were first calculated for each pair of scientific disciplines. The dimension reduction of the initial cosine similarity matrix was conducted using cluster and hierarchical principal component analysis (HPCA). The results of the cluster analysis were presented elsewhere (Hristovski, 2012). Due to the space restrictions we present here only the results from the HPCA analysis. Distances d between science fields were calculated as $d = 1 - q;$ where q is the Salton's cosine similarity (the overlap order parameter) between the vectors which defined the conceptual spaces of scientific fields. The order parameter q as a measure of conceptual coherence was projected within the space of two principal components which gave visually tractable image of the position of scientific fields in the conceptual space spanned by those PCs. The plot of the d values between separate scientific disciplines within that space was conducted by a quadratic fitting procedure where the maxima corresponded to the actual d values between certain scientific disciplines. The average d value, for each cell, was than projected within the PC space. This procedure enabled a visualization of the structure of basins of attraction, i.e. the domains of conceptual coherence, and the saddle points representing the linguistic barriers between scientific fields.

The maximum population entropy (Haken, 2000) was calculated for the system of PCs extracted under Kaiser-Guttman criterion and Varimax rotated, for assessing the information change and the degree of self-organization within the space of scientific language as a consequence of induction of the NDST-SP explanatory principles. Each principal component posseses a population entropy $I_i = \ln \lambda_i + 0.5 \ln \pi + 0.5$, where λ_i represents its eigenvalue. The total population entropy I_t of the PC system equals the sum of the individual population entropies of the extracted PCs. Lower entropies signify the reduction of information within the conceptual space, i.e. an increased coherence in the linguistic communication. The maximum of the population entropy means that it is calculated for the system of independent primary PCs. If they are not independent, but correlated, and reveal more simple secondary structure, the population entropy would attain smaller values.

RESULTS AND DISCUSSION

For easier apprehension Figures 1 and 2 may be interpreted as a topographic map or landscape in which the deep-bordeaux color regions represent deep valleys (basins of attraction) belonging to certain scientific language and the deep-green regions the high plateaus of the landscape which maximally separate scientific languages. All other colors represent possible passages (saddle points) from discipline to discipline requiring less than maximal conceptual (informational) transformation for mutual communication. To pass from one valley to another one means to transform the language (pass over the hill or barrier) for some quantity proportional to the distance d as defined further in the text.

The absence of the NDST-SP explanatory principles lead to compression of the original 10 vectors to four PCs with eigenvalues $\lambda_1 = 3.8$; $\lambda_2 = 2.46$; $\lambda_3 = 1.4$; and $\lambda_4 = 1.02$ explaining 86% of the total variance. The reduction of dimensionality and the information compression is mostly due to the language similarities between neighbouring sciences. The primary PCs were weakly correlated and resulted in one secondary PC which was saturated mostly by the natural science concepts while other scientific disciplines were sharing less information with this component possesing low projections. More on the interesting structure of the PCs is given in Hristovski, 2012).

In the absence of the NDST-SP explanatory principles the inter-science conceptual communication form a narrow channel and exist only as a consequence of linguistic nearest-neighbor interactions, whereas between the others there are maximal barriers given in deep-green color (see Fig. 1). The total maximal population entropy calculated for the four extracted primary PCs was I_t = 5.575 nats (natural units). This state corresponds to the conceptual space of the high school and undergraduate university textbooks analyzed or to the explanatory connectedness between scientific disciplines by the early 70-es. The dominance of the nearest-neighbor and absence of long-range connectedness between scientific disciplines arises as a consequence of overlapping concepts mainly between neighboring disciplines. The attractor basin structure resembles a canyon-like configuration in which the path leads through small barrier saddles connecting neighboring scientific disciplines. The explanatory communication between more distant disciplines, say CR and PP or CS, needs a large, sometimes maximal conceptual, i.e. language, restructuring and thus represent pathways of exploration with vanishing probability. This means that a learner would hardly detect a connection between distant scientific disciplines.

The presence of the NDST-SP explanatory principles lead to compression of the original 10 vectors to three PCs with eigenvalues λ_1 = 5.76; λ_2 = 1.62; and λ_3 = 1.04; explaining 85% of the total variance. This significant reduction of dimensionality and information was a consequence of language similarities not only between neighbouring but also due to sharing common explanatory concepts between widely separated sciences. The primary PCs were strongly correlated and resulted in one secondary PC which was highly saturated by all scientific disciplines almost equally. See more on this in Hristovski, 2012).

The presence of the NDST-SP explanatory concepts, on the other hand, brings about lowering of the barriers and formation of a coherent linguistic domain enabling direct linguistic communication even between fields, classically deemed distant and unconnected, such as PP, MB or CS and CB on the one hand and EP or and CL on the other. The total maximal population entropy calculated for the three extracted primary PCs was I_t = 4.346 nats, and it was lower than in previous case for about 1.23 nats or equivalently 1.77 bits, a clear consequence of information compression. According to Haken (Haken, 2000), the information compression within the system is a hallmark of self-organization and existence of increased

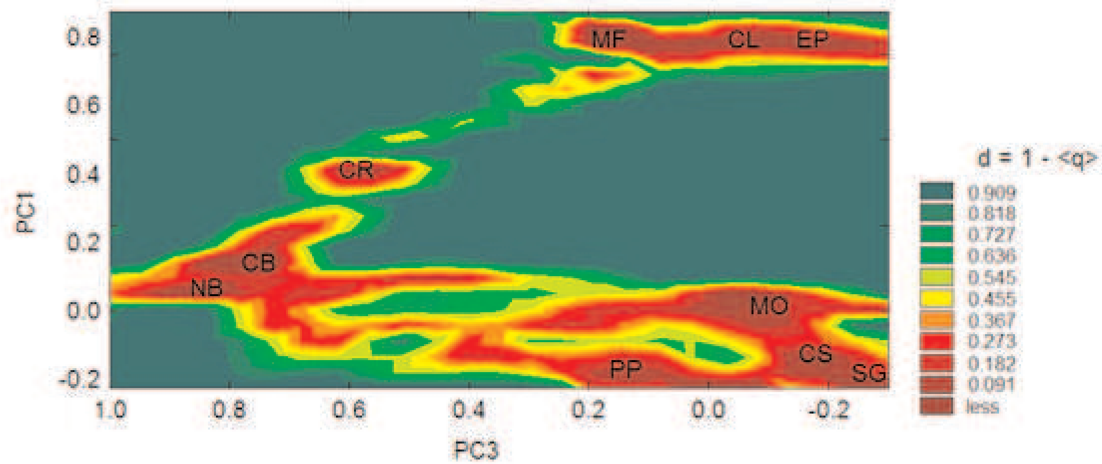

Fig. 1. Basins of attraction and saddle points between scientific fields in absence of general NDST-SP principles in the space spanned by the first and the third principal components (this combination was choosen for visual convenience). The communication between fields is constrained in a narrow channel between conceptually neighbouring disciplines. A state of low linguistic coherence. EP-elementary particles physics; CL-cosmology; MP-molecular physics; CR-chemical reactions; CB-cell biology; NB-neurobiology; MB-motor behavior; PP-psychological processes; CS-collective sports, SG-sociology of groups.

coherence. In other words NDST-SP explanatory concepts play the role analogous to catalysts in chemical systems which lower the barriers between the initial and final states, easing the transformation to occur. It is interesting to note that particularly the tendency of fragmentation between the domain of sport sciences and other scientific disciplines is being suppressed.

Generally speaking, whereas separate scientific fields *maintain* their context dependent language (inter-scientific conceptual distances *d* do not go to zero – see Fig 2), the general NDST-SP concepts form an embedding *explanatory* attractor basin within which a stabilizing synthetic knowledge becomes a feasible perspective. The learning process, then, may be defined as a hopping, metastable, dynamics within the general basin of attraction. It becomes obvious that the learning dynamics would be different in the two cases fields a new emergent *explanatory pattern* is taking place in the last 2-3 decades, enabling a novel synthetic world view. General explanatory concepts or explanatory language play the role of correspondence which forms a stable link among the models of organized matter at different levels. Synthetic thinking thus, viewed epistemologically, becomes an emergent property of science based on the coherence revealed by the increase of the <*q*> collective variable and the decrease of the populational entropy of the system. The property is emergent since the whole of scientific understanding becomes different than the specialized knowledge within each of scientific disciplines, however still containing the specific, context dependent explanations within each scientific discipline as special cases. Science reveals itself as a *complex learning system* whose macroscopic behaviour in the conceptual space is represented by the conceptual

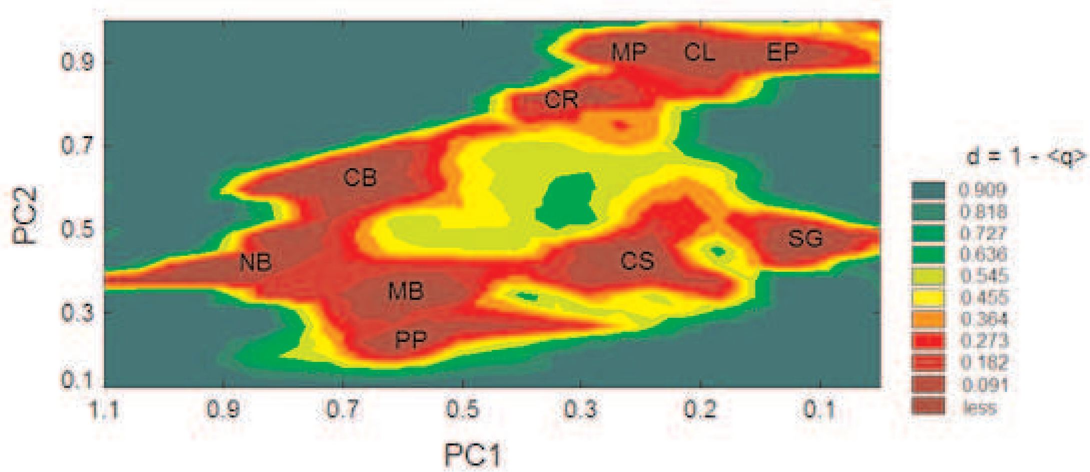

Fig. 2. Basins of attraction and saddle points between scientific fields in presence of general principles NDST-SP in the space spanned by the first two principal components. The communication between fields is confined in a narrow channel between conceptually neighbouring disciplines. A state of lower linguistic coherence. EP-elementary particles physics; CL-cosmology; MP-molecular physics; CR-chemical reactions; CB-cell biology; NB-neurobiology; MB-motor behavior; PP-psychological processes; CS-collective sports, SG-sociology of groups.

depicted in Fig. 1 and 2. Whereas in Fig. 1 the hopping dynamics is severely constrained within the narrow path connecting neighboring scientific fields, the basin of attraction depicted on Fig. 2 enables much more versatile hopping among fields and hence larger exploratory breadth.

Within this model scientific research may be envisioned as a self-organizing process embedded in the linguistic space in which as a result of cooperative, synergic, processes between scientific overlap order parameter.

Empirical scientific concepts are basically context dependent where the context is formed by the energy and length scales of the system under study. The traditional explanatory concepts are context dependent as well. However, recent developments clearly progresses toward their explanation through more general and thus unifying theoretical framework. This theoretical framework may be called ‘context free’. However, this depends on the way we look at it. If we use the bottom-up strategy, the more general and hence more abstract explanatory terms become truly context free. Conversely, if we apply the top-down strategy, than, since these general explanatory concepts are valid for all levels, they become pluri-contextual, i.e. valid for each of the specific levels of organized substance. In this sense the emergent explanatory pattern is characterized by both: coherent explanatory skeleton, as well as *flexibility* through its context dependence.

The above-mentioned process of generalization is akin to the renormalization procedures used in statistical mechanics. In statistical mechanics the renormalization procedure tells us which parameters of the system remain valid for different description levels of the system under research. One renormalizes, or transforms, the system's model from microscopic toward macroscopic description and finds out that some parameter of interest, say temperature, stays relevant for all those levels. Other parameters of the microscopic description fade out as the scale of description gets larger. Hence, an accurate macroscopic description would be impossible without taking into account the temperature as a relevant parameter, but other microscopic variables may be neglected. Let's use this analogy and instead of physical variables we treat the explanatory concepts. In similar vein, the general concepts from SP and NDST survive the renormalization procedure, i.e. the change of levels of organized matter, and stay relevant, structurally stable, on each of them separately. They survive the coarse-graining transformation procedure of explaining the levels of description from micro to macroscopic, from quantum field and string theory to social systems. This may be envisioned as a special case of evolution, i.e. as a *scientific evolution under selective pressure*, which eliminates the context dependent concepts and stabilizes the context free ones as the fittest. Seen epistemologically, the role of the selective pressure here is played by the process of change of the level of description, or the level of substance organization, seen ontologically. Such general explanatory concepts point to the existence of a kind of *correspondence principle* penetrating across the levels of organized matter. In this sense the interplay of such general explanatory concepts at different levels of substance organization make the backbone of that very organization. A careful reader will also notice that the very model of scientific language self-organization presented here is, in fact, based on the same explanatory principles belonging to the NDST-SP conceptual complex.

INSTEAD OF CONCLUSION

A brief note on possible applications of the synthetic thinking

In the previous text an attempt has been made to model the change within the scientific conceptual space heading toward larger explanatory linguistic coherence (Fig.2). This was not reflected in the structure of high school and undergraduate university textbooks (Fig.1). One of the reasons for this may be that these explanatory concepts are used dominantly within the frameworks of advanced formal models dealing with specific fundamental processes at each level. This, on the other hand, needs a minimum level of mathematical sophistication to be implemented. The enhanced migration of mathematicians and physicists in biological sciences already changed the picture in this realm of investigation. In future we might expect this migratory wave to proceed toward even more distant fields such as sports science and sociology and there are already such examples.

On the other hand, these general explanatory concepts are rather intuitive and may be implemented for the education purposes rather straightforwardly already at the high school education level, if not earlier, in the higher grades of elementary education in a form of a separate educational program. This stems from the very nature of the education program which would be not directed toward acquiring technical skills and specific knowledge, but toward forming a worldview underpinned by the unifying NDST-SP backbone of the scientific language. This would need a new profile of a teacher, a teacher who would play the role of a *catalyst* of the synthetic thinking on the tenets of what was described in the previous text. Similar to the catalysts in natural systems her/his role in the education would be to bring the specific, i.e. context dependent, scientific explanations closer to one another and enable students to couple them by lowering the informational barrier through the use of unifying explanatory concepts. The role of the synthetic thinking teacher would be one of an *enabler* or *facilitator* of explanatory synthesis. The role of physical activities and sports within this educational framework is wide and will be discussed elsewhere.

Acknowledgement

This research was financed by the University of "Ss. Cyril and Methodius" program for research projects, No. 02-663/28 from 14.09.2012.The author expresses his gratitude to Natalia Balague on her inspiring and supporting comments on the ideas presented in this paper.

REFERENCES

Cvitanović, P., Jensen, M.H., Kadanoff, L.P., & Procaccia, I. (1984). Renormalization, unstable manifolds, and the fractal structure of mode locking. *Physical Review Letters,*55, 343-346.

Englert, F. Brout, R. (1964). Broken Symmetry and the Mass of Gauge Vector Mesons. *Physical Review Letters,* 13**,** 9, 321.

Glansdorff, P, Prigogine, I. (1971). *Thermodynamics Theory of Structure, Stability and Fluctuations*. London, Wiley-Interscience.

Haken, H. (1964). Theory of Coherence of Laser Light. *Physical Review Letters,* 13**,** 9, 329-331.

Haken, H. (2000). *Information and Self-Organization: A Macroscopic Approach to Complex Systems.*Springer-Verlag Heidelberg.

Higgs, P. (1964). Broken Symmetries and the Masses of Gauge Bosons. *Physical Review Letters*, 13**,** 16, 508.

Hopfield, J.J. (1982). Neural networks and physical systems with emergent collective computational abilities. *PNAS,*79, 2554-2558.

Hristovski, R. (2012). Toward a model and application of interdisciplinary links of the sports sciences and physical education with other areas of academic knowledge based on the concepts of the complex systems theory. Book of accomplished projects for 2012 at the University of Ss. Cyril and Methodius,115-122.

Isnard, C.A., & Zeeman, E.C. (1974). *Some models in the social sciences*. Use of models in the social sciences, Tavistock, London, 44-100.

Kadanoff, L.P. (1966). Scaling laws for Ising models near T_c. *Physics*, 2, 263.

Kelso, J.A.S., Southard, D., & Goodman, D. (1979). On the nature of human interlimb coordination. *Science, 203,* 10291031.

Landau, L.D. (1969). *Collected Papers*, Nauka, Moscow

Laughlin, R.B., & Pines, D., Schmalian, J., Stojković, B.P., & Wolynes, P. (2000). The Middle Way. *PNAS.*, 97,1, 32-37.

Mainwood, P. (2006). *Is more Different. Emergent properties in Physics*. PhilSci Archive. Oxford.

Pollack, G.H & Chin, W.C. (2008). *Phase Transitions in Cell Biology*. Springer.

Wilson, K.G. (1975): The renormalization group: critical phenomena and the Kondo problem. *Revews of Modern Physics,* 47, 4, 773.

Wolynes, P., Onuchic, J.N., & Thirumalai, D. (1995). Navigating the Folding Routes. *Science,* 267,1619-1620.

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СИНТЕТСКО МИСЛЕЊЕ ВО НАУКАТА (ЗА СПОРТОТ). САМООРГАНИЗАЦИЈА НА НАУЧНИОТ ЈАЗИК

УДК:796:001.8(05)
(Оригинален научен труд)

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Апстракт

Презентирана е скица на еден феноменолошки модел на само-организација во просторот на научни концепти со нагласок на позицијата на науките за спортот. Добиениот модел има нерамна структура на вгнездени базени на привлекување и динамиката на учење е дефинирана како преминување помеѓу концептуалните простори на посебните научни дисциплини, вгнездени во генералниот базен на привлекување. Трудот анализира како промената на специфичните и генералните објаснувачки концепти ја менуваат структурата и динамиката на учење. Кога концептите со висока објаснувачка општост се отсутни структурата станува фрагментирана и взаемно слабо поврзана или потполно неповрзана што кореспондира со моменталната состојба во научното образование. Наспроти тоа, кога таквите објаснувачки принципи се присутни, висината на јазичните бариери значајно опаѓа и системот од концепти се реорганизира во структура на поврзани базени на привлекување што овозможува обединување на привидно одделните области на знаење. Општите објаснувачки концепти играат улога на 'катализатори' кои ги намалуваат информациските бариери помеѓу концептуалните простори на науките и обезбедуваат поголема веројатност за пронаоѓање на нивните меѓусебни врски. Понатаму накратко дискутираме како објаснувачките принципи од нелинеарната динамика и статистичката физика можат да станат основа за еден нов вид на образовна програма и профил на учител.

Клучни зборови: *наука, наука за спортот, образование, синтетско размислување, концептуална самоорганизација, самоорганизација на научниот јазик*