

Considerations about Mechatronics Integrative Transdisciplinary Knowledge

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Abstract: The purpose of this paper is to describe the ongoing transdisciplinary way of establishing mechatronics as a paradigmatic teaching-learning process (epistemological mechatronics), as a socio-interactive way of living (ontological mechatronics), and as a reflexive communicational language (semiotic mechatronics) with a logical creativity and flexibility for the purpose of crossing barriers and the building of bridges between students and teachers, between students and the mechatronics as subject and between the students themselves, in a learning-understanding synergistic process, as active-reactive, extrinsic-intrinsic approach, with a functional-axiological evaluation of the achievement of mechatronics knowledge from the transdisciplinary perspective. The paper presents a transdisciplinary approach of the knowledge process through mechatronics learning. The type of the synergistic-significant process in a transdisciplinary context of learning in the knowledge based society explains the functional-informational integration at the level of structures, the logical-creative signification and the ethical-moral valuing of the entire spectrum of knowledge, including the spiritual dimension, using the top-down and bottom-up perspectives in mechatronics knowledge process. Due to this fact that the understanding of the present world cannot be accomplished within the framework of a single disciplinary research, transdisciplinarity is the only way of explaining complementarity both to multidisciplinary and crossdisciplinary research, in a codisciplinary context, being entirely distinct from them. Because multidisciplinary and crossdisciplinarity temporary cross disciplinary boundaries, remaining within the framework of a disciplinary context, they cannot explain the integrative mechatronics knowledge. Because of this very important reason the present paper is a better explanation, through the presented model, than the other existing models of the synergistic identity of mechatronics, in the context of a transdisciplinary approach.

1. What really mechatronics is?

Starting from 1969, the term „mechatronics” emerged in Japan and reflects the merging of mechanical and electrical engineering disciplines. Later, mechatronics was considered as an electrified mechanism, and was explained to be a new engineering discipline, as a boundary between mechanics and electronics [Dinsdale, Yamazaki 1989]. Today, the term encompasses a large array of technologies, merging of mechanics,

electronics and software and information technology [Yamazaki, Miyazawa,1992]. Mechatronics gained legitimacy in academic circles in 1996 when mechatronics was defined as "the synergistic integration of mechanical engineering with electronics and intelligent computer control in the design and manufacturing of industrial products and processes." [Harashima, Tomizuka, Fukuda,1996; Auslander, 1996]. The general category of mechatronics should accomplish a number of topics as modeling and design, system integration, actuators and sensors, intelligent control, robotics, manufacturing, motion control, vibration and noise control, micro devices and optoelectronic systems, automotive systems, robotics and other applications [Grimheden, Hanson, 2001; Minor, M. A., Meek, 2002]. The very important question is not the definition of mechatronics but what really it is [Comerford 1994; Pop, Maties, 2008]. The areas under mechatronics as defined in that initial issue, would be very broad, and would include topics that have very little in common, so a transdisciplinary approach of mechatronics should be done, considering that mechatronics is, at the same time, an educational paradigm by its thematical, exemplifying, interactive, functional aspect (mechatronical epistemology) [Grimheden, Hanson, 2005], as a socio-interactive system of thought, of living and mechatronical action (mechatronical ontology) and a reflexive way of communication (the creative logic of the included third) [Nicolescu,1996], integrating in a synergistic combination mechanical engineering, electronics, control engineering, and computers, through the design process, as a reflexive creative language [Pop, Maties, 2008; Pop, 2008]. Based on information, mechatronics is not only the best suited technology for a highly advanced informational society with the mattergical incorporation of the inform-action [Gitt, 2006], as an emerging engineering area that is likely to modify the fundamental nature of engineering education, in the disciplines of electrical and mechanical engineering, but it involves the application of complex decision making to the operation of physical systems, mechatronical systems depending for their unique functionality on computer software, and can provide an academic model for developing co-disciplinary programs within the engineering college departmental structure that is historically based on the traditional engineering disciplines. Mechatronics integrates the classical fields of mechanical engineering, electrical engineering, computer engineering, and information technology to establish basic principles for a contemporary engineering design methodology.

As an argument that mechatronics isn't nor pluridisciplinary, crossdisciplinary, a new discipline, or a simple methodology, but a transdisciplinary epistemological, logico-creative and ontological system, is obviously sustained through the model from fig.1 [Pop, Maties, 2008]. Here are presented the five stages of the evolution of the mechatronics from disciplinary to transdisciplinary, through codisciplinary, pluridisciplinary and cross-disciplinary, as follows: **(1) disciplinary approach, with specific separation** between mechanical engineering, electronics and intelligent computer control in an attractive context, with no contact between them; **(2) co-disciplinary approach, with statistical virtual connection**, identified between separated disciplines, the disciplinary dynamics generating temporary contents and methods in a specific configuration; **(3) pluri-disciplinary approach, cooperation through contact**, characterized by different kinds of contacts between disciplines with radial mutual interactive flows through each contact point; **(4) cross-disciplinary approach as a combination by overlapping**, with common creative-innovative spaces, with transfer of methods and content. Circular flows determine the emergence of a new systemic configuration in a paradigmatic system, a reflexive communicational language and a socio-interactive reorganization of the contents and methods. This kind of informational flow is prevalently. Consequently, the closed regions are growing from the initial points of contact to space filled with the separated elements, so the last level of integrative, as a **transdisciplinary approach by synergistic synthesis (5)** emerges in a new transdisciplinary informational-functional structure, with ethic-semantic values, including the spiritual dimension. This system has a central hard

synergistic core with flexible and deformable boundaries, surrounded by a “fluid belt” through which are captured innovative ideas, new research themes and new courses in synergistic specific configurations and programs from the diffuse outer shell. The central zone is functioning as a paradigmatic (educational), socio-interactive (existential) and reflexive (communicational) transdisciplinary system [Pop, Maties, 2008]. If in the cross-disciplinary stage circular flows of knowledge are prevalent, in the transdisciplinary context a radial anisotropy of attractive-repulsive combining flows, with a hierarchical-heterarchical rebuilding of the contents emerges (could be just emerging new transdisciplinary thematic disciplines as robotics, optomechatronics, biomechatronics, etc.). The nodal points (inner, medium and outer) as they are seen in fig.1, are introduced as possible channels for explanation of the transdisciplinary thematic, experiential selection, interactive participative communication and functional legitimacy mechatronical educational paradigm [Grimheden, Hanson, 2005].

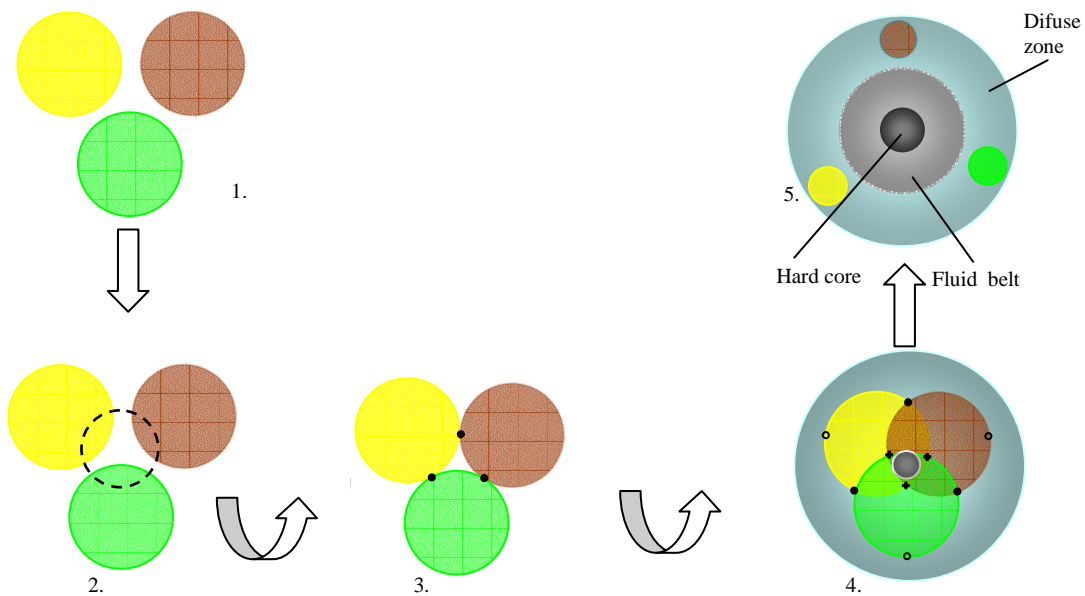


Fig 1. The new perspective on paradigmatic transdisciplinarity in semiophysics [Pop, Maties, 2008]

2. Top-down & Bottom-up Perspectives in Mecahtronical Knowledge

The growing importance of Mechatronics, from a pluridisciplinary one at the beginning, through crossdisciplinary, and more recently, as a transdisciplinary approach to engineering [Pop, Maties, 2008], becomes increasingly apparent. New products and systems based on the integrated application of mechanical, electronic and computing engineering technologies are demonstrating complexity, increased performance, and often, previously impossible capabilities. These advantages have been stimulated by factors including developments in microprocessors, new and improved sensors and actuators, advances in design and analysis methods, simulation tools and novel software techniques [Minor, Meek, 2002]. The key aims of the mechatronical approach of knowledge are to promote relevant education and training, support the development of research programs and diffuse information relating to the application of techniques across all industrial sectors [Grimheden, Hanson, 2003].

Mechatronics is studied at a theoretical and practical level, as well, a balance between theory, an analysis and hardware implementation being emphasized, based on the physical understanding rather than on the mathematical formalities. In the same time case-study, problem-solving approach, with video hardware demonstrations are used

throughout the mechatronics thematic courses [Doebelin, 1980]. In this way there is the possibility to explain what mechatronics is in a general philosophical framework, with the possibility to approach the mechatronics evolution from a **top-down perspective** as a philosophy of living with a specific language and with strong educational skills in the knowledge based society. At the same time there is a **bottom-up perspective** in this approach of reaching knowledge, the integration of new products and systems based on the mechatronics synergistic synthesis with complexity, increased performance, and to achieve skills in a transdisciplinary apprenticeship relation between the teacher and the students as transmitter and receiver of the contextual synergistic message, as is presented in fig.3 [Pop, 2008]. The true mechatronics engineer has a genuine interest and ability across a wide range of technologies, and who takes delight in working across disciplinary boundaries in a transdisciplinary way, to identify and use the particular blend of technologies which will provide the most appropriate solution to the problems. Furthermore, an engineer could be a high communicator who has the knack of being able to motivate others about technologies outside their own, and to promote alternative approaches. The knowledge search window is a methodological concept introduced by the author to explain the bottom-up/top-down mechanism of the teaching-learning process in mechatronics educational paradigm from transdisciplinary perspective. The teacher is acting from a top-down perspective, while the student from a bottom-up perspective, the ranks of authority being alternatively in a symmetrical and complementary interaction state, depending of the context to avoid potential conflicts by building bridges, working together in an assumed/negotiated harmony, in the same time avoiding the possible disharmony states [Pop, 2008].

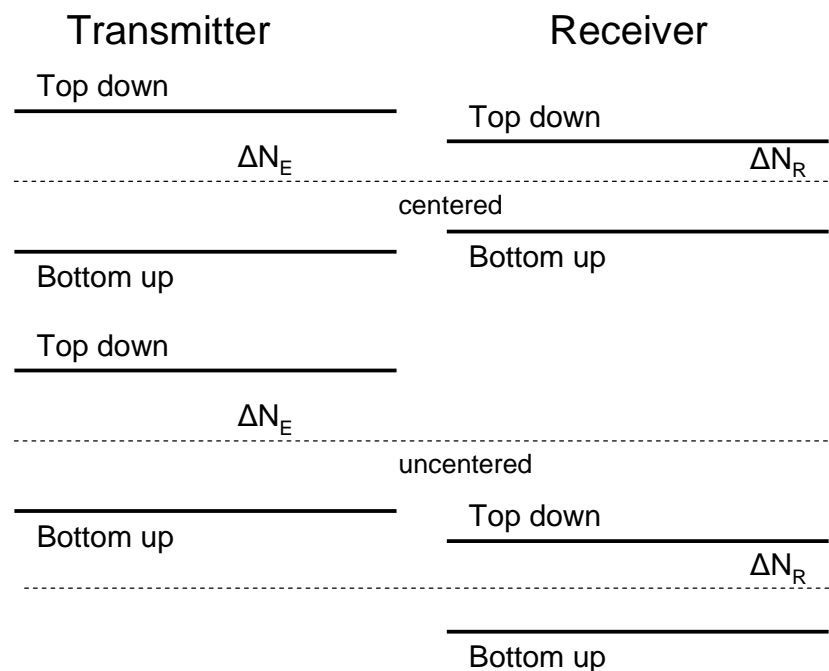


Fig.2. Knowledge search window

The mechatronics curricula studies strive to develop in each student a balance between the top-down and the bottom-up perspectives on mechatronics approach of knowledge, studying in depth the key areas of technology on which successful mechatronics designs are based and thus lays the foundation for the students to become true mechatronics (mechatronics engineers). To evaluate concepts generated during the design process, without building and testing each one, the mechatronics engineer

must be skilled in the modeling, analysis, and control of dynamic systems and understand the key issues in hardware implementation [Wikander, Torngren & Hanson, 2001; Hanson, 1994]. It is very important to develop a hierarchy of physical models for a dynamic system, from a real, natural model to a design model, and understand the appropriate use of this hierarchy of models, and its heterarchical levels, to achieve the key elements of a measurement system and the basic performance specifications and physical/mathematical models of a variety of analogical and digital motion sensors, the characteristics and models of various electromechanical actuators (brushed dc motor, brushless dc motor, and stepper motor) and hydraulic and pneumatic actuators, analog and digital circuits and components and semiconductor electronics as they apply to mechatronical systems [Palm, 1999]. Then the mechatronical engineer has to be able to apply various control system design techniques, as open-loop feed-forward control, classical feedback control (root-locus and frequency response), and state-space control, to have a general understanding of more advanced control design techniques (cascade control, inferential control, model predictive control, adaptive control, fuzzy logic control, and multivariable control) [Minor, Meek, 2002, Giurgiutiu, Lyons, Rocheleau, Liu, 2005]. The digital implementation of control and basic digital control design techniques have to be learned and understood to be able to use a microcontroller as a mechatronical system component, i.e., understand programming and interfacing issues, and to apply all these skills to the design of a mechatronical system and of the intelligent products. By intermediating the creation of these intelligent products, which incorporate an increasing amount of information, containing a high amount of intelligence and complexity, mechatronical technology can assure the conservation of matter and energy resources, by processing less matergy and by polluting less, thus being a no dissipative technology, in an intelligent environmental context [Pop, 2006; Gitt, 2006].

As the needs of humanity seem to be satisfied, there is an increase in actions which seek the fulfillment of spiritual needs, through knowledge, which, in turn, creates a powerfully informatized based society. In the knowledge based society, information being flexible, unlimited, infinitely extensible, can assure the fulfillment of these spiritual needs, at the same time with the material ones [English, 2000; Pop, 2006]. Mechatronics have lead, in a short amount of time, to the development of new educational principles through the development of systemic thinking, the development of skills for team work, where thinking and action flexibility, designing and production creativity are essential qualities for the researcher. In mechatronical technology, the design process can be finalized only by a team of specialists from different fields who must learn to communicate in a new manner, which means that each researcher must think synergistically rather than sequentially, from his own field of research. There is an obvious difference between the traditional, fragmented, sequential and the mechatronical integrative design [Stiffler, 1992]. The principles of mechatronical education can be applied successfully to all teaching levels, thus creating the necessary environment for defining the curricular areas with the possibility to switch from a unilateral thinking, based on a single discipline, to a flexible, global thinking, which assures an integrating approach to the educational process [Hanson, 1994; Rainey, 2002; Grimheden, Hanson, 2005].

Mechatronics can be regarded as an educational paradigm, as a reflexive contextual language and as a socio-interactive way of being (living, thinking, acting), with a methodology to achieve an optimal design of electromechanical intelligent products, to put in practice the ideas and techniques developed during a transdisciplinary process to raise synergy and provide a catalytic effect for finding new and simpler solutions to traditionally complex problems [Pop, Maties, 2008]. This approach is a top-down evaluation of the mechatronical knowledge perspective. There is a synergy in the integration of mechanical, electrical, computer and information systems for the design and manufacture of products and processes, which can be generated by a correct combination of parameters, so that

the final product be better than just the sum of its parts. Without a synergistic combination, mechatronical products could not exhibit performance characteristics that were previously difficult to achieve. A mechatronical concentration area in the engineering curriculum would support the synergistic integration of precision mechanical engineering, electronics control, and systems thinking into the design of intelligent products and processes. Considered as a result of applying information technology to physical systems, consisting of mechanical, electrical, electronic and computer systems as well as actuators, sensors, and real time interfacing, mechatronics use sensors and actuators to transduce energy between high power, usually the mechanical side, and low power, the electrical and computer or electronic side. This is one of the possible bottom-up approaches of mechatronics. Transdisciplinarity as understanding (top-down approach), learning and practicing it (bottom-up approach) is based on an active process, occurring either intentionally or spontaneously, that enables to control information, thus to question, integrate, reconfigure, adapt or reject it [Nicolescu, 1996].

3. Learning to know and learning to understand in transdisciplinary mechatronics

Transdisciplinarity has four pillars of knowledge: learning to know, learning to do, learning to be and learning to live with. There is one very obvious inter-relation between these four pillars of the new system of education: how to learn to make (to do) while learning to know, and how to learn to be while learning to live together with [Nicolescu, 1996]. To learn and to understand are the most two important issues of the transdisciplinary mechatronical knowledge in the integrative process through modeling and control in the design of mechatronical systems with the physical and mathematical modeling. The way the mechatronics works as a transdisciplinary in the new educational paradigm, was presented before, by its thematical, exemplifying, interactive, functional aspects (mechatronical epistemology), as a reflexive way of communication (the creative logic of the included middle), and as a socio-interactive system of thinking, living and mechatronical action (mechatronical ontology) [Rainey, 2002; Grimheden, Hanson, 2005], was explained in fig.1.

To achieve knowledge in transdisciplinary mechatronical context, it is necessary to reconfigure the framework of the way these four pillars of transdisciplinary knowledge are working. For this aim, were put together, in a new framework, learning as achieving information and knowledge, as an objective extrinsic logical issue, and understanding as an ethic-semantic issue, the subjective spiritual dimension of knowledge. Learning to learn to know by doing, and learning to understand to be by living together with other people are two guidelines to achieve both necessary integrative semiophysical skills in a synergistical communicational context, structural-functional semiophysical system, with its technical efficiency (knowing what and how we know), and ethico-semantic value of semiosocial products in an ethical authoritative context with its axiological coefficient (knowing how and why we live) [Pop 2008]. Every pillar of transdisciplinary knowledge can be integrated in this framework to explain the mechatronical perspective of achieving knowledge in the informational society with a new transdisciplinary mechatronical epistemology, a new creative logics of the included middle and a new mechatronical ontology. Learning to know becomes a ring of the extrinsic active knowledge chain, with its aspects what, how and why epistemic questions, related with the message (quantitative and qualitative aspects, know what), with the manner of the communicational process, code and channel (know how) and finally with the context (know why) (fig.3). The “training in the methods which help us to distinguish what is real from what is quite illusory and to have intelligent access to the fabulous knowledge of our age” [Nicolescu,1996; OECD, 2004], in the context of the emergence of continuously connected beings to build a new scientific spirit, to establish bridges between the different

disciplines, and between the meanings of these disciplines and the capabilities of the inside transdisciplinary potentialities as an indispensable complement to the disciplinary approach, and finally, to adapt themselves to the necessary and continuously changing of professional exigencies, with a permanent flexibility always oriented towards the actualization of their inside, is of big importance for mechatronical knowledge, but only learning by doing. This ring, of the extrinsic active knowledge chain, by doing, represents the “acquiring a profession necessarily passing through a phase of specialization in a challenging world, with changes induced by the computer revolution with excessive specialization risks, reconciling the exigency of competition with equal chance and opportunity for all” [Niculescu, 1996]. Learning by doing could be, in the transdisciplinary approach of mechatronics, an apprenticeship in creativity [Siegwart, 2001], discovering what is new, bringing to light the creative potentialities, generating the conditions for the emergence of the authentic person, working at the top level of creative potentialities [Boden, 1994; Niculescu, 1996]. The intrinsic reactive branch of the mechatronical transdisciplinary knowledge, that of the learning to understand, involves the spiritual dimensions of the knowledge process without which the knowledge couldn't be understandable. The first step is learning to be, a permanent apprenticeship in which teachers inform the students, as much as students inform the teachers, in a permanent teaching-learnig process, so that the shaping of a person inevitably passes through a transpersonal dimension with fundamental tensions between the material and the spiritual, discovering the harmony or disharmony between individual and social life, testing the foundations of our believes in order to discover that which is found underneath, questioning in a scientific spirit being a precious guide for us [Niculescu, 1996; Berte, 2005].

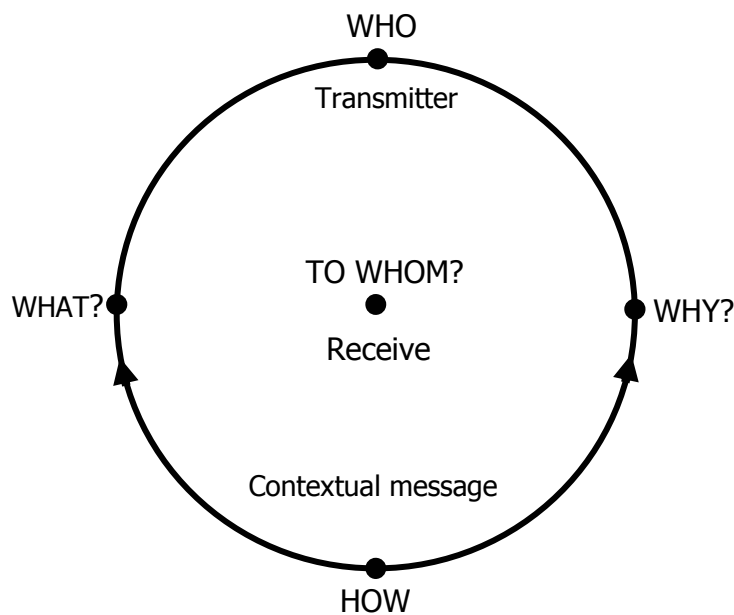


Fig.3. Semiophysical synergistic communicational model

This can be done only living together with other people in communion, not of the simple toleration of the differences between people, but supposing that the transgressive (transcultural, transreligious, transpolitic and transnational) attitude can be learned allowing us to a better understanding own culture, to better defend the personal and collective identity with national, religious, socio-cultural and political convictions. The transdisciplinary approach is based on the equilibrium between the outside (with its extrinsic active knowledge aspect) of the person and his inside (with its intrinsic reactive knowledge aspect) in a equilibrium balance. So, transdisciplinary mechatronical knowledge, with its extrinsic active (learning to know by doing) and intrinsic reactive (understand to be by living with) components can be

presented in a new original manner. The knowledge by „learning to learn to know by doing” involves „creativity through quality and innovation (to know-what, how, why)”, combining with „action through competence and performance (by doing-who, what, how and why)”, as extrinsic active component, characterized by the efficiency of knowledge process. On the other hand there is the knowledge “by understanding to be by living with”, which presupposes „authenticity through integrity and excellence” (to be-who, how), together with „participation through communion and apprenticeship (by living with-to whom)”, as intrinsic reactive component, characterized by its axiological ethic-semantic parameter [Pop, 2008].

4. Conclusions

It is very important to know that mechatronics is not a simple discipline, a new postmodern utopia, but it works through the new transdisciplinary educational paradigm by its thematical, exemplifying, interactive, functional aspect (mechatronical epistemology), through its socio-interactive system of thought, of living and mechatronical action (mechatronical ontology) and a reflexive way of communication (the creative logic of the included third). In the same time mechatronics is not a simple working methodology, but it works with specific synergistic synthesis methodologies. Mechatronics has not a pluridisciplinary or a crossdisciplinary character but a transdisciplinary one, generating new disciplines in a codisciplinary context, with flexible and contextual curricula (robotics, optomechatronics, biomechatronics, etc). Mechatronics evolves in a transdisciplinary context through knowledge search window mechanism defining the bottom-up and top-down flexible limits in the process of achieving knowledge in the knowledge-based society, from a transdisciplinary perspective using transdisciplinary knowledge methodology with its four pillars of knowledge in an original framework, as is proposed, learning to learn to know by doing and learning to understand to be by living with together.

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