A TRANSDISCIPLINARY APPROACH OF THE MECHATRONICAL EDUCATION IN THE CONTEXT OF THE KNOWLEDGE BASED SOCIETY

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Abstract

The paper presents the new perspective of the transdisciplinary approach in the mechatronical knowledge as a synergistic-significant teaching/learning integrative process in the knowledge based society, using the search window methodology with top-down and bottom-up levels of knowledge. At the same time, starting from the transdisciplinary learning paradigm, were introduced the extrinsic active and intrinsic reactive syntagms to modeling the new paradigms of the transdisciplinary mechatronical education. Research gives a new perspective on that the mechatronics has to be considered, an educational paradigm, a reflexive way of communication (the creative logic of the included third) and a socio-interactive system of thought, living and action, as well.
Key words*: transdisciplinarity, mechatronics, integrative knowledge, teaching/learning process, knowledge search window.*

Introduction

The transdisciplinarity as a new kind of achieving knowledge in the context of knowledge based society is complementary to the traditional disciplinary one, different from the multidisciplinary and from crossdisciplinary as well (Nicolescu, 1996; Berte, 2003), being a very important aspect for mechatronical education (Pop, Maties, 2008; Comerford, 1994). This process implies a necessary multi-dimensional opening of the mechatronical studies, in the every dimension of the new knowledge based society, the Universities, the civil society, the places of production of the new knowledge and products, the cyber-space-time, to attend the aim of universality and for a redefinition of values governing the existence (Nicolescu, 2002; OECD, 2004; Berte, 2005). While disciplinary research concerns, at most, one and the same level of Reality, or fragments of one level of Reality, transdisciplinarity concerns the dynamics engendered by the action of several levels of Reality at once (Nicolescu, 2002). The discovery of these dynamics necessarily passes through monodisciplinary, codisciplinary, multidisciplinary and crossdiciplinary rings of the knowledge chain, the last one being transdisciplinarity (Nicolescu, 2002; Pop, Maties, 2008), nourished by disciplinary research, not confused with it, but better clarified by the new way of mechatronical transdisciplinary reflexive communication, that of the creativity (De Bono, 2003; Boden, 1996). As in the case of disciplinarity, transdisciplinary research is not antagonistic, but complementary to multidisciplinarity and

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crossdisciplinarity research because the understanding of the present world cannot be accomplished within the framework of the only disciplinary research. So, monodisciplinarity, codisciplinarity, multidisciplinarity, crossdisciplinarity and transdisciplinarity are working together, like arrows shot from a single bow, the knowledge (Nicolescu, 2002). Because of the bridges existing between the different disciplines, the emergence of multidisciplinarity and crossdisciplinarity is a very important sequence of steps towards the next step, that of transdisciplinarity (Nicolescu, 1996), in the very new codisciplinary context (Saillant, 2006), even at a horizontal heterarchic level of the different disciplines, or at the vertical hierarchical structure of different levels from the transdisciplinary educational perspective, as well (Pop, Maties, 2008). From the transdisciplinary point of view it is very important *what* and *why* we are doing, but it is more important *how* we are doing what we do (Feldenkrais, 1997).

About mechatronics

Mechatronics is considered as a "synergistic combination between precision mechanical engineering, electronic control and systemic thinking in product and process design, and represents a major need for the integrating research as well as for the educational programs" (Comerford, 1994; Bolton, 2003), becoming an imperative of the informational society. The third wave of knowledge integration, determines the moving of an increasingly large part of the population towards information manipulation activities (Toffler, 1983). 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 information based society (English, 2000; Nicolescu, 1996). Mechatronics, based on information, is not only the best suited technology for a highly advanced informational society, but also a new educational paradigm by its thematic, exemplifying, interactive, functional aspect (mechatronical epistemology) (Grimhedden 2005), as a reflexive way of communication through design, modeling (the creative logic of the included third) (Berte, 2005; Nicolescu, 1996) and a socio-interactive system of thought, of living and action (mechatronical ontology (Nicolescu, 2002; 1996). In the knowledge based society, information is flexible, unlimited, infinitely extensible, and so, it can assure the fulfillment of spiritual needs, at the same time with the material ones. By the creation of final products which incorporate an increasing amount of inform-action, containing a high amount of intelligence and complexity, mechatronical technology can assure the conservation of matter and energy resources (mattergy), being such a nondisipative, a conservative and an ecological technology, as well (Gitt, 2005; Pop, 2008). Mechatronics have lead 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 any researcher (Boden, 1994; De Bono, 2003). 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, on one hand, that each of the members must think synergistically, rather than sequentially, and on the other hand, the researcher must study thoroughly his own field of research. So, 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 (Wikander, 2001; Grimhedden, 2005). Mechatronics cannot be considered as a new methodology for studying a simple combination of the multidisciplinary contents. Mechatronics is not just a crossdisciplinary overlap of disciplines; even the emergence of new disciplines is present in an epistemological degree of knowledge in an applicative context (Pop, 2008). Mechatronics, based on information, is not only the best suited technology for a highly advanced informational society with the mattergic (matter and energy) incorporation of the inform-action (information and intentional action as well) (Gitt, 2005), but as was presented before, it is a new transdisciplinary way to achieve knowledge in the informational society (Pop, Maties, 2008). 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. At the same time case-study, problem-solving approach, with video hardware demonstrations are used throughout the mechatronical thematic courses (Grimhedden, 2005; Doebelin, 1980). 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 (Berte, 2003; Rainey, 2002).

The Semiophysical Model of the Mechatronical Communicational Knowledge

The transdisciplinary mechatronical educational paradigm can be better understood through the synergistic semiophysical contextual communication model, which allows a systemic approach of the teaching/learning process. The model emphasizes efficient functioning structures (laboratories, human-machine learning systems, think-tank informal structures, ice-breaking groups, etc.) with an ethic-semantic valuing coefficient of semiotic products in knowledge processes, such an integrative functional-informational process exhibits a spiritual dimension of knowledge in an informational society and has the capacity to explain in a synergistic way the process of knowledge in a transdisciplinary context (Pop, 2008). In fig.1 is presented the semiophysical contextual communication model which integrates the most important models and is working with the key questions: who, what, how, why and to whom (with whom). At the transmitter's level (who, which) there is the authoritative-expressive principle (*Pathos)*, with its rules, responsibility, credibility, deference. The receiver's space (to whom, with whom) is governed by the participative-conative principle (*Ethos)*, with rules of receptivity (choice), availability (accountability), involvement (action). The contextual message is working through the cooperative-referential principle (*Logos)*, with rules of the quantity and quality of the message (what), the contextual relevance of the message (why) and the manner of transmission, code and channel (how) (Pop, 2008).

Message (what)
Transmitter (who) ---Receiver (to whom)
Code – Channel (how), Context (why)

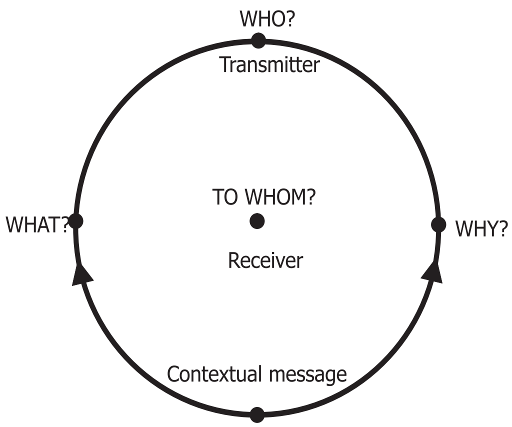

Figure1. The semiophysical contextual communication model.

There is the possibility to explain what mechatronics is in a general conceptual framework, with the possibility to approach the mechatronical 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 mechatronical 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 (Pop, 2008). The true mechatronical engineer (mechatronician) (Harashima, 1996; Rainey, 2002) has a

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genuine interest and ability across a wide range of technologies, being able to work 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 (Minor, 2002). Furthermore, an engineer could be a high communicator who has the knack of being motivated to motivate others about technologies outside their own, and to promote alternative approaches.

The knowledge search window is a methodological concept introduced to explain the bottom-up/top-down mechanism of the teaching-learning process in mechatronical educational paradigm from a transdisciplinary perspective (Pop, 2008; Pop, Maties, 2008). 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, by avoiding the barriers, working together in an assumed/negotiated harmony, in the same time avoiding the possible disharmony states. Transdisciplinarity as a top-down and bottom-up approach, as a search window methodology in achieving knowledge through understanding, learning and practicing mechatronical skills is based on an active-reactive understanding-learning process, occurring either intentionally or spontaneously, that enables to control information, thus to question, integrate, reconfigure, adapt or reject it (Nicolescu, 1996; Pop, 2008). The mechatronical curricula studies strive to develop in each student a balance between the top-down and the bottom-up perspectives on mechatronical approach of knowledge, studying in depth the key areas of technology on which successfully mechatronical designs are based and thus lays the foundation for the students to become true mechatronicians (mechatronical engineers) (Stiffler, 1992; Harashima, 1996; Rainey, 2002). Mechatronics can be regarded as an educational paradigm, as a reflexive contextual language and as a socio-interactive way of being, as a lifestyle (thinking, living, 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 (Berte, 2005; Pop, Maties, 2008). This approach is a top-down evaluation of the mechatronical knowledge perspective.

In mechatronical technology, the design process as a very important component of the new transdisciplinary reflexive language 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 (Berte, 2005; Rainey, 2002; Grimheden, 2005).

Transdisciplinary paradigms and syntagms in mechatronical knowledge

Transdisciplinarity has four pillars of knowledge: *learning to know, learning to do, and learning to be and learning to live with others* (Delors 1996). 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 (Stiffler, 1992). 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, they were put together, in a new framework, learning to learn as achieving information and knowledge, as an objective extrinsic logical issue, and learning to understand 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 syntagmatic guidelines to achieve both necessary integrative semiophysical skills in a synergistic communicational context, structural-functional semiophysical system, with its technical efficiency (knowing what and how we know), and ethic-semantic value of semiosycal products in an ethic 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, new creative logics of the included middle, and new mechatronical ontology. Learning to know becomes a ring of the extrinsic active knowledge chain, with its aspects of "what", "how" and "why" 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"). We need training in the methods which help us to distinguish what is real from what is quite illusory with an intelligent access to the fabulous knowledge of our age, in the context of the emergence of continuously connected beings to build a new scientific spirit. We need 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. We need to adapt the disciplines to the necessary and continuously changing of professional exigencies, with a permanent flexibility always oriented towards the actualization of their inside. We need to open windows towards the knowledge field in the information based society. All these have to be done being of a big importance for mechatronical knowledge, but only "learning by doing" (Pop 2008, Nicolescu 2002). As a 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" (Nicolescu, 1996). Learning by doing could be, in the transdisciplinary approach of mechatronics, an apprenticeship in creativity (Siegwart, 2001, Boden 1994), 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; Nicolescu 1996).The intrinsic reactive branch of the mechatronical transdisciplinary knowledge, of the "learning to understand", involves the spiritual dimensions of the knowledge process without which the knowledge couldn't be understandable (English 2000; Pop 2008). 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-learning 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 (Nicolescu 1996, 2002). 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 an 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 is presented in a new original syntagmatic-paradigmatic manner. The knowledge by „learning to learn to know by doing" involves „creativity through quality and innovation (to know-what, how, why)", working in „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 component "by understanding to be by living with", which presupposes „authenticity through integrity and excellence" (to be-who, how), together in „participation through communion and apprenticeship (by living with-to whom)", as intrinsic reactive component, characterized by its axiological ethic-semantic parameter (Pop, 2006).

Conclusions

As a very important conclusion of the research is a new transdisciplinary perspective of the mechatronical knowledge as follows:

a. Transdisciplinary knowledge learning paradigm (Delors 1996):
   - "hard" component: *" learning to do"," learning to know";*
   - "soft" component: *" learning to be"," and learning to live together with others.*

b. Transdisciplinary knowledge learning syntagms (Nicolescu 1996):

-"hard" component:*" how to learn to do while learning to know";*
-"soft" component: "*how to learn to be while learning to live together with others"*.

c. Transdisciplinary knowledge teaching/learning syntagms:

1. Extrinsic active transdisciplinary knowledge syntagm: "by learning to learn to know by doing", with teaching/learning paradigm, characterized by the structural-functional efficiency of knowledge process:
   -*„creativity"* with *"quality"* and *"innovation" (to know-what, how, why)",* in
   -*„action"* with *"competition"* and" *performance" (by doing-who, what, how and why).*
2. Intrinsic reactive transdisciplinary knowledge syntagm: "by learning to understand to be by living with others", with learning/understanding paradigm, characterized by the ethic-semantic parameter of knowledge process:
   -*„authenticity"* through *"integrity"* and *"excellence" (to be-who, how),* and
   -*„participation"* through *"communion"* and *"apprenticeship" (by living with others, who-to whom, with who).*

So, the transdiciplinary paradigmatic-syntagmatic sequences presented before work as successive top-down and bottom-up search windows allowing better understanding of the synergistic-integrative process in the semiophysical contextual message communicational model, with "who, what, how, why and to whom (with who)" questions to achieve knowledge in the context of the mechatronical informergic (informaction as information and intentional action, with mattergy as matter and energy) knowledge based society.

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