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Transdisciplinary Approach of the Mechatronics in the Knowledge Based Society

Ioan G.Pop[1] and Vistrian Mătieş[2]
[1]*Emanuel University Oradea*
[2]*Technical University of Cluj Napoca*
Romania

"*The intuitive mind is a sacred gift and the rational mind is a faithful servant. We have created a society that honor the servant and has forgotten the gift* "
(A. Einstein)

1. Introduction

Mechatronics and transdisciplinarity came into the light in the 1970's as multiple integrative possibilities to understand the way to achieve, transfer and incorporate knowledge in the context of the new informational society, the third wave of evolutionary process towards the informergical, knowledge based society, by transdisciplinary mechatronical revolution (Masuda, 1980; Toffler, 1983; Peters & Van Brussel, 1989; Kajitani, 1992; Klein, 2002; Pop & Vereş, 2010).
When the word "*mecha-tronics"* was invented, most people have had no idea about what it could be (Mori, 1969). Mechatronics has been associated with many different topics including manufacturing, motion controle, robotics, intelligent controle, system integration, vibration and noise controle, automotive systems, modeling and design, actuators and sensors, as well, as microdevices, as electromechanical systems, or controle and automation engineering (Kajitani, 1992; Erdener, 2003; Bolton, 2006). The term mechatronics is represented as a combination of words, *mecha*nisms and elec*tronics*, other some combinations being created before, as "*minertia*," a name for a servomotor line that used "*min*imum in*ertia*" to develop super-fast ability for machine to start and stop. Another term, "*mochintrol*", a short name for "*mo*tor, ma*chin*e and con*trol*", represents electrical actuators able to controle freelly mechanical components (Ashley, 1997). The *mechatronics* is the most used, most representative term, and finally accepted to define this new engineering field of knowledge, which began to gain popularity until the middle of 1980's (Auslander, 1996), the most commonly used one emphasizes synergy ([1]), "mechatronics is the synergistic integration of mechanical engineering with electronics and intelligent computer control in the design and manufacture of industrial products and processes"(Harashima et al, 1996).
During the 1970's, mechatronics focused on *servotechnology*, in which simple implementation aided technologies related to control methods such as automatic door openers and auto-

focus cameras (Bolton, 2006). In the 1980's, mechatronics was used to focus on *information technology* whereby microprocessors were embedded into mechanical systems to improve performance (Kyura & Oho, 1996; Gomes et al, 2003). Finally, in the 1990's, mechatronics centered on *communication technology* to connect products into large networks, including the production of the intelligent systems, technologies and products (Auslander, 1996; Isermann, 2000). Mechatronics is increasingly focused on the development of systems that synergize wide range of technologies and techniques, such as intelligent and precise mechanisms, smart sensors, to enhance information feedback computation power and information processing capabilities motion devices (Siegwart, 2001; Bolton, 2006). Mechatronics has been increasingly accepted as a methodology and as a new way of thinking in its own parameters. Mechatronical thinking, methodologies, and practices were applied to develop products with incorporated intelligence with multiple functionalities and enhanced by people as inform-actional agents ([2]) (Auslander, 1996; Giurgiutiu et al., 2002; Pons, 2005; Bolton, 2006; Habib, 2007; Pop & Mătieş, 2008a).

The meaning of the word *mechatronics* is somewhat broader than the traditional term electromechanics, being at a glance only an ambiguous, amorphous, heterogeneous, and continually evolving concept with a lot of definitions, many of which with a broad or a narrow significance, mechatronics being considered as "an engineering design philosophy applied with the synergy of disciplines to produce smart, flexible and multifunctional products, processes and systems" (Kaynak, 1996; Erdener, 2003; Habib, 2007). Another definition consider that "mechatronics is a unifying interdisciplinary paradigm that is capable of fulfilling such challenges, which make possible the generation of simpler, economical, robust, reliable and versatile intelligent products and systems" (Habib, 200). There is a significant design trend that has a marked influence on the product-development process, in manufactured goods, the nature of mechanical engineering education and quite probably in engineering management (Kerzner, 2003). Today, as the need for mechatronics continues to expand, the term which defines this new integrative field of knowledge becomes more and more common, two things contributing to its growth, the shrinking global market and the need for reliable and cost-effective products (Kerzner, 2003; Arnold, 2008). To be competitive, companies must develop new technologies to design and manufacture their products, as a rapid reaction to change, for competitive product properties and shortened product cycles (Arnold, 2008; Montaud, 2008). While mechatronics still involves the merging of mechanics and electronics, it also includes software and information technology, melding new technologies to the existing, combining them to solve problems, creating products or even developing new ways to obtain things by integrating different technologies to solve efficiently the emerging problems (Bolton, 2006). If in the past engineers tried to use their own lines of study to solve a problem, now they need to use the thought processes of many different outlooks to enhance their research with the use of more efficient tools in a transdisciplinary framework (Arnold, 2008; Nicolescu, 1996; 2006; Pop & Mătieş, 2010). During the time and with technological advancements mechatronics has become a familiar term in the field of engineering worldwide, but although the foundations for mechatronics were set, its full potential is yet only partially expressed, mechatronics being considered an open system of the knowledge achievement (Nicolescu, 1998; Berian, 2010). About the future of mechatronics, the transdisciplinary approach opens new perspectives on its development, incorporating more and more ideas which will be accounted to improve the way to do things and to live in the new context of ever-changing needs and willings of a complex and complicated world, when innovations and technologies have to be improved and developed with the rapidly changing times (Mieg, 1996; Nicolescu, 1996 ; Jack & Sterian, 2002; Pop & Maties, 2009). In the next years mechatronics will increasingly oriented on safety, reliability and affordability, with efficiency, productivity, accountability and controle, with a very important role in the biotechnology, as well as in computerized world and parts of industry-based manufacturing, incorporating the computer as a part of the machine that builds a product (Jack & Sterian, 2002). Mechatronics gives to the engineer a new perspective with greater possibility to achieve and to use knowledge, so that concepts can be developed more efficiently, the communications with other engineering disciplines being improved, the major goals in the field of mechatronics being oriented to the client and market satisfaction, as well (Harashima, 2005; Montand, 2008; Arnold, 2008).

The most important thing is to know what mechatronics is, what isn't and how does it work, mechatronics being not a simple discipline ([3]), a new postmodern utopia, working through the new transdisciplinary transthematic educational paradigm by its exemplifying selection (what), interactive communication (how), and functional contextual legitimation (why) aspects (Grimheden, 2006; Berian, 2010). Mechatronics can be considered as a synergistic integrative system of Scientia, as a new educational transdisciplinary paradigm (mechatronical epistemology), of Techne, working as a reflexive language of the integrative design (the creative logic of the included middle) ([4]), and as Praxis, through a new socio-interactive system of thought, living and action (mechatronical ontology) (Mieg, 1996; Wikander et al, 2001; Nicolescu, 2002; Grimheden & Hanson, 2001; Bridwell et al, 2006; Pop, 2009). At the same time mechatronics cannot be considered as a simple working methodology (Auslander, 1996; Giurgiutiu et al., 2002), but it works with specific synergistic synthesis methodologies (Erdener, 2003; Ashley, 1997; Pop, 2009a). Mechatronics has not simply multi(pluri)disciplinary (Day, 1992; Giurgiuțiu, 2002), nor an inter(cross)disciplinary character (Arkin, et al, 1997; Siegwart, 2001; Grimheden, 2006; Habib, 2008), but a transdisciplinary one (Ertas et al, 2000; Pop & Mătieş, 2008a; 2010; Pop, 2009; Berian 2010), generating new disciplines in a codisciplinary context (Pop & Mătieş, 2008; 2009) with flexible and contextual curricula (robotics, optomechatronics, biomechatronics, etc) (Hyungsuck, 2006; Cho, 2006; Mândru et al., 2008).

The proposed aim of the paper is to introduce a new transdisciplinary perspective on the mechatronical integration of knowledge in the context of the new framework, the knowledge based-society, considered as the informergic (informaction integrated in mattergy) society, based on advanced knowledge. Only the transdisciplinarity knowledge achievement can explain the way the creativity, with a synergistic signification (see 1), works as an intentional action through ideas, design, modelling, prototyping, simulation, incorporating informergically the inform-action in matt-ergy, to realize smart products, sustainable technologies and specific integrative methods to give solution to the emerging problems ([5]). Real experiences cannot be replaced by learning only with simulations, for this being necessary to use complementarily, the virtual tools as design, modelling, simulation and the real world representations as prototyping, building smart mechatronical products, technologies and systems. The transdisciplinary way of knowledge is the only way to realize the integration of the rational knowledge of things and relational understanding of the world (Nicolescu, 1996; Pop, 2009), so the mechatronical knowledge achievement can be fulfilled only through the transdisciplinarity, as an open system of the integrative knowledge (De Gruyter, 1998; Nicolescu, 2002; 2008; Berte, 2005; Berian, 2010). This new paradigm ([6]) of the knowledge achievement implies an intellectual convergence towards some comon principles articulated and distributed (defined, taught and trained), with a mastery of these by new practitioners, the mechatronicians (workers, technicians, engineers) ([7]). The paradigm shift requires a re-interpretation of prior theory, a re-evaluation of the prior fact, with a reconstruction applied to new situations and re-assessed in previous ones (Cleveland, 1993; Scott & Gibbons, 2001; Arnold, 2008). This new paradigm works in a new state of equilibrium until an another challenge comes to provide another paradigm transition. From this perspective mechatronics can be considered as a brand, searching the identity evolving through different stages, in an continually emerging crisis, considered as an evolutionary chain of levels of reality in the knowledge field, all the keywords presented showing important ingredients of the mechatronical system in a continuous and dynamic development of the market conditions as a direct result of generation of high technology products incorporating complex and increased number of functionalities. (Ramo & St Clair; 1998, Arnold, 2008; Mătieş et al, 2008).

2. How does really mechatronics work, disciplinary or transdisciplinary?

2.1 Transdisciplinary mechatronical knowledge system

Knowledge refers to the state of knowing, acquaintance with facts, truths, or principles from study or investigation. A discipline is a branch of knowledge, instruction, or learning which is held together by a shared epistemology, as assumptions about the nature of knowledge, by the barriers, methodologies as acceptable ways of generating or accumulating knowledge. The terms multi(pluri)disciplinary ([8]), inter(cross)disciplinary ([9]) and transdisciplinary ([10]) refer to "multiple disciplinary system", in the theory of knowledge, some disciplines being considered closer together, while other disciplines being deemed farther apart, with a very distinctive distance between disciplines (epistemological distance). On the basis of epistemological proximity, disciplines are often clustering into groups, or knowledge subsystems such as: natural sciences (physics, chemistry, biology), social sciences (psychology, sociology, economics), humanities (languages, music, visual arts), among others, some of them using quantitative methods, while other relying on qualitative methods. Disciplines that belong to the same knowledge subsystems are closer together, but those that belong to different subsystems are farther away from each other. The disciplinary level of knowledge is working at the thematic-curricular level in the predisciplinary, monodisciplinary or codisciplinary context ([11]), while the professional programs and reasearch groups generally operate on a multi(pluri)disciplinary model (methodological level), being more than disciplines, and in some cases may bridge across knowledge subsystems working at the synergistic level (structural-interdisciplinarity, functional-crossdisciplinarity and generative-transdisciplinarity) *as a multiple disciplinary thinking perspective* of the knowledge (Choi & Pak, 2008; Pop & Vereş, 2010). When are combined, disciplines more disparate or epistemologically different from one another are giving new insight for a complex problem or issue than disciplines that share similar epistemological assumptions, the differences between disciplines provide alternative methods and perspectives, making it possible to see all the facets of the reality in a complex context, leading to the cognitive process of emergence of new ideas and knowledge perspectives, the more disparate are the disciplines, the more different are the perspectives, with a greater chance of success in tackling the complex problems (Palmer, 1978; Arecchi, 2007). Knowledge is considered to be expressed in a large spectrum represented as a continuum at one side, where it is almost completely tacit, as semiconscious and unconscious knowledge held in people's heads and bodies, as hands-on knowledge (Nonaka & Takeuchi, 1994; Polanyi, 1997). At the other side of the spectrum, knowledge is almost completely explicit, accessible to people, other than the individuals originating it, represented as a line - or band - structured spectrum of the knowledge, as hands-in and hands-off knowledge. Explicit elements are objective, rational and created "then and there" (top-down level), while the tacit elements are subjective, experiential and created "here and now" (bottom-up level) (Leonard & Sensiper, 1998). It is interesting to study the way the knowledge can or cannot be quantified, captured, codified and stored as well, the predominant aspect in the management of tacit knowledge being to try to convert it in a form that can be handled using the "traditional" approach, through the transdisciplinary process of the knowledge integration: hands-on (passive knowledge), hands-in (passive-active knowledge) and hands-off (active knowledge). There is a difference between know-what (selection the message to be knowledge communicated), as an explicit, and know-how (the way the message is codified and transmitted), as implicit knowledge (Brown & Duguid, 1991; Pop, 2008), procedures being known as a codified form of know-how that guide people in how to perform a task. The organizational (communion-like) knowledge constitutes core-competency and it is more than "know-what", requiring the more elusive "know-how" - the particular ability to put know-what into practice" as know-how (Hildreth et al, 2000; Gomes et al, 2003). To develop knowledge through interaction with others in an environment where knowledge is created, nurtured and sustained the Communities of Practice (CoPs) provide for people an adequate environment (Wenger & Snyder, 2000; Hildreth & Kimble, 2004) ([12]), where transactive knowledge (the organisation's self - knowledge - knowing what you know) and resource knowledge (knowing who knows what) are focusing on the knowledge of the organisational environment ([13]) (Hildreth et al, 2000). In the knowledge based-society, the education and training build on option for transdisciplinarity, represent a necessity in the new context of education and a guarantee for future success, at the same time with a new attitude, an active participation, flexibility and adequation to the context, transforming any problem into an opportunity (Berte, 2003; Pop & Mătieş, 2010). Transdisciplinarity, as doing and being approach of knowledge achievement, is based on an active process that enables the actors of the educational training environment, as a teaching factory (Alptekin, 1996; Lamancusa et al, 1997; Berte, 2003; Quinsee & Hurst, 2005), to use successfully the information, to question, integrate, reconfigure, adapt or reject it (Nicolescu, 1996). The framework of transdisciplinary approach on education presupposes the formulation and affirmation of original opinions, the rational choice of an option, the problem solving, the responsible debate of ideas, the process of teaching-learning beyond matter boundaries, beyond even the traditional academic rules. The best space for the transdisciplinary approach of knowledge achievment is the University, where inquiry can roam freely, as the natural home of the synergistic integration (Castells, 2001), with its flexibility and adaptiveness in the knowledge economy, a space often deconstructed, if not completely under erasure, in a continuous possible reconfiguration in a combination of a high required degree of competence in the different disciplines (breadth approach), but with the necessity to have a deapth profile of the knowledge in research on own cognitive field ([14]) (Kaynak, 1997). Transdisciplinarity can also explain the sustainability concept, in education and in development of the achievment of integrative knowledge systems (Gibbons et al, 1994; Hmelo et al, 1995; Hildreth et al, 2000; Arnold, 2008; McGregor & Volckmann, 2010).

Because the knowledge resides in people, not in machines or documents at all, this very important aspect is determining the spiritual dimension of knowledge (Reason, 1998; Pop, 2009), because the contemporary man is considered as an agent involved in the knowledge process, through a balance between the rationality in the knowledge of things (by doing) and the relationship in order to understand the world (by being) (Nicolescu, 1996; 2008). The paradigm shift in the knowledge process is necessary to encourage and support necessary changes in education, identifying and acknowledging critically and creatively the major tendencies that have determined modifications of the education purposes leading to a reviewing of curriculum in a creative innovative context ([15]) (Langley et al, 1987; Boden, 1994).

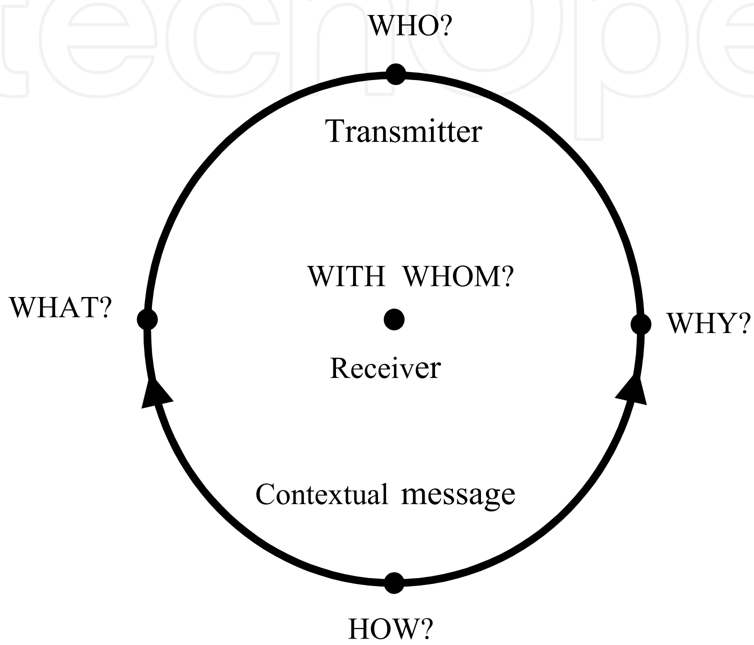

Fig. 1. The transdisciplinary contextual message model (Pop, 2008).

From a transdisciplinary point of view, disciplinary research concerns, at most, one and the same level of Reality, but in most cases, it only concerns fragments of one level of Reality, but transdisciplinarity concerns the dynamics engendered by the action of several levels of Reality at once, the discovery of these dynamics necessarily passes through disciplinary knowledge, being nourished by disciplinary research, and the codisciplinary research is clarified by transdisciplinary knowledge in a new fertile way (Nicolescu, 1996; Klein, 2002). In this sense, disciplinary (*deapth aproach*) and transdisciplinary research (*breadth approach*) are not antagonistic but they are working in the *"breadth through deapth"* complementarly paradigm, opening a new vision in the knowledge achieving process (Kaynak, 1996). In order to explain in an integrative way the process of knowledge achievement in the transdisciplinary context, was elaborated the *transdisciplinary contextual message model* ([16]) (fig.1), as a systemic perspective of the knowledge achieving process by communication, with functional structures, producing signs, signifying them and valuing the educational products of knowledge processes in an ethic-semiotic context, with the key synergistic significant questions: *who-with whom, what, how* and *why* (Pop, 2008). The questioning paradigm "*what, how* and *why*" of the mechatronics is a very important transdisciplinary approach for the emergence of the brand profile of the mechatronics itself (Harashima et al, 1996; Bradley, 1997; Buckley, 2000; Grimheden & Hanson, 2003; 2005).

2.2 The transdisciplinary knowledge search window

In the context of the necessity of a new kind of the mechatronical knowledge achievement are identified two well known problem solving strategies, namely bottom-up and top-down approaches in design literature as knowledge search window ([17]), as a new transdisciplinary approach, that of the included middle, with creativity in action and authenticity through participation (Lupasco, 1987 ; Nicolescu, 1996 ; Waks, 1997; De Bono, 2003; Pop & Mătieş, 2008a). The creativity in action is a very important way to facilitate the rational knowledge of things (by doing) through the adequateness and innovation for creativity and through competition and competence for action, to teach the disciples to improve their thinking to reflect on their creations and to find possibilities how to develope them in general patterns of lateral and vertical thinking, complementarly in their technological projects (Waks, 1997; De Bono, 2003; Pop & Mătieş, 2008a). A creative system must be able to detect the original ideas, to perform an efficient exploration with intelligent search strategy for admissible states and for moving from one state to another (Boden, 1994; Langley et al 1987; Savary, 2006). To be creative does mean to explore and possibly to transform the "conceptual space"([18]), the most important thing being "the identification, stimulation and evaluation of creativity" (De Vries, 1996; Doppelt & Schunn, 2008). Tradition and innovation are not opposed one to another, they are working together, the most creative individuals being considered those who explore a conceptual structure going beyond them, in a transdisciplinary way, the real giants being those determined individuals who manage to discern and articulate new structures which transgress the existing ones (Boden, 1994; Schäfer, 1996).

Today a mechatronical engineer has to understand and to work in the new synergistic relationship between precision engineering, control theory, computer technology and sensors and actuators technology. Achieving this objective requires a paradigm shift from the sequential to simultaneous engineering, in an integrative educational approach that seeks to develop systemic thinking learners and teachers as well. As an engineering field mechatronics is focused by training professionals to master the practical skills necessary for mechatronical systems design and maintenance, the new educational principles being focused on the creative concurrent design and development process. There are several intuitive touchstones for creative achievement, such as the complexity of the questions answered, its centrality or importance for the field explored. To learn the trade is to learn these structures, and to be creative is to produce new applications at the individual P-creativity level, or at the scientific community H-creativity level (Boden, 1994).

The knowledge search window is introduced as a methodological concept to explain the bottom-up/top-down mechanism of the teaching-learning process in the mechatronical educational paradigm from a transdisciplinary perspective (Pop & Mătieş; 2008a; Pop, 2009a). This methodology is working in achieving mechatronical knowledge process by learning, understanding and practicing mechatronical skills, being based on an active-reactive understanding-learning process, occurring either intentionally or spontaneously, enabling to control information, to question, integrate, reconfigure, adapt or reject it (Nicolescu, 1996; Berte, 2005). The teacher is considering as acting from a top-down perspective, while the disciples from a bottom-up perspective, the ranks of authority of the teacher and the disciples being alternatively in a symmetrical and complementary interaction state, depending of the synergistic context, in order to avoid potential conflicts, building bridges, avoiding the barriers, working and living together, as human beings in a permanent connection between them and with intelligent systems, technologies and products, as well (Nicolescu, 1996; Berte, 2005; Lute, 2006; Mătieş et al, 2008; Pop & Vereş, 2010). It is necessary to develop in each student a balance between these top-down and the bottom-up perspectives on mechatronical approach of knowledge, studying in depth the key areas of technology on which successfully mechatronical design are based and thus lays the foundation for the students to become true mechatronicians (workers, technicians, engineers) (Day, 1992; Pop, 2009a) in the vocational educational training systems (VETS), as a knowledge factory (Stiffler, 1992; Alptekin, 1996, Lamancusa et al, 1997; Rainey, 2002; Erbe & Bruns, 2003). To fulfil the demands for multi-skilled technicians and skilled workers, vocational educational training systems (VETS) together with industry are confronted with the need to develop theoretical sequences (top-down perspective) integrated with practical learning sequences (bottom-up perspective), in acquiring key competences and update the skills as a continuous all life learning process. There are considered three areas in order to achieve the proposed objectives by sustainable long term efforts: (1) *raising advanced knowledge level (as wisdom and skill achievement, as well)*, in order to avoid the risks of economic and social exclusion (the future labour markets in the knowledge-based society will demand higher skill levels from a shrinking work force); (2) *all the life learning* (*lifelong learning, lifewide learning and learning for life) strategies,* including all levels of education, the qualification frameworks and the validation of non-formal and informal learning, as well; (3) *the knowledge triangle, education, research and innovation*, which plays a key role in boosting jobs and growth, accelerating reform, promoting excellence in higher education and university-business partnerships, ensuring that all the fields of education and training are ready to play a full role in promoting creativity, innovation and development (Schäfer, 1996; Barak & Doppelt, 2000; De Bono, 2003; Derry & Fischer, 2005; Pop, 2009a; Pop & Mătieş, 2010).

As the bottom-up strategy produces solutions at physical, practical level, top-down design strategy looks for original ideas at functional level before investigating physical solution alternatives, being possible to explain what mechatronics is in a general engineering framework. The possibility to approach the mechatronical evolution from a top-down perspective as a living conceptual system, with a specific language and with strong educational skills in the knowledge based society is connected with the bottom-up perspective in the approach of reaching knowledge, the integration of new products, technologies and systems. This process is based on the mechatronical synergistic synthesis with complexity, increased performance to achieve skills in a transdisciplinary apprenticeship relation between the teacher and the disciples as transmitter and receiver of the contextual synergistic message. The key questions "what, how and why" in the mechatronical knowledge process, as a communicational interface between the teaching-learning fields of knowledge environment, „who with whom", are the fundamental pillars of the knowledge based society building (Gibbons et al, 1994; Harashima et al, 1996; Bradley, 1997; Buckley, 2000; Fuller, 2001; Klein, 2002; Pop, 2008a; Fricke, 2009).

Mechatronics can be considered 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 intelligent products, to put in practice the ideas and techniques developed during the transdisciplinary process to raise synergy and provide a catalytic effect for finding new and simpler solutions to traditional complex problems (Berte, 2005; Everitt & Robertson, 2007; Nicolescu, 2008; Berian, 2010). The integrative design process is an top-down evaluation approach of the mechatronical knowledge perspective, being a very important component of the new transdisciplinary reflexive, creative integrated design language, as a new informergic transdisciplinary code (Pop, 2009). The design process could be finalized only by a team of specialists from different fields who must learn to communicate in a new transdisciplinary manner, each researcher working synergistically rather than sequentially, from his own field of research, with an obvious difference between the traditional, fragmented, sequential and the mechatronical integrative concurent design (Hewit & King, 1996; Lamancusa et al, 1997; 9 Ertas et al, 2000; Habib, 2008; Doppelt & Schunn, 2008). The principles of mechatronical education can be applied successfully to all teaching levels, creating the necessary teaching-learning environment, as a teaching factory, as a mobile mechatronical platform, or as another educational systems (Stiffler, 1992; Alptekin, 1996; Lamancusa et al, 1997; Arkin et al, 1997; Rainey, 2002; Erdener, 2003; Erbe & Bruns, 2003; Quinsee, 2005; Papoutsidakis et al, 2008; Mătieş et al, 2008). It is necessary to define curricular areas with the possibility to switch from a unilateral monodisciplinary thinking, based on a single discipline, to a flexible, global thinking, which assures an integrating approach to the educational process, as a synergistic generative transdisciplinary way (Berte, 2005; Rainey, 2002; Grimheden & Hanson, 2005).

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 fields (Kyura & Oho, 1996; Iserman, 2000; Minor & Meek, 2002). These advantages have been stimulated by factors including developments in microprocessor industry, new and improved sensors and actuators, advances in design and analysis methods, simulation tools and novel software techniques (Stiffler, 1992; Langley et al, 1987; Wikander et al, 2001; Shetty, 2002; Pons, 2005; Mătieş et al, 2005). Mechatronics is studied at a theoretical and practical level, as a balance between theory and practice, through the included middle approach of knowledge (Lupasco, 1987; Nicolescu, 2008), based on the physical understanding rather than on the mathematical formalism, in a mechatronical integration process of the physics as phenomenological, methodological and material sciences points of view emphasized through analysis and hardware implementation (Langley et al, 1987, De Vries, 1996, Wikander et al, 2001, Bolton, 2006). To evaluate concepts generated during the design process the mechatronicians must be skilled in the modelling, analysis, and control of dynamic systems and understand the key issues by computational explorations of the creative process (Jack & Sterian, 2002; Mătieş et al, 2005). The true mechatronical expert (engineer, worker, technician) has a genuine interest and ability across a wide range of technologies, and 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 emerging problems. Such an expert has to be a high communicator who has the knack of being able to motivate others about technologies and to promote alternative approaches (Rainey, 2002; Quinsee & Hurst, 2005). It is very important to develop a hierarchy of physical models for dynamic systems, from a real, natural model to a design model, and understand the appropriate use of this hierarchy of models, and its vertically structural system levels, to achieve the key elements of a measurement system and the basic performance specifications and digital motion sensors, the characteristics and models of various actuators, analogical and digital circuits and components, with semiconductor electronics (Comerford, 1994; Isermann, 2000; Bolton, 2006). At the same time the mechatronician has to be able to apply various control system design techniques, the digital implementation of controle and basic digital controle design techniques have to be learned and understood in order to be able to use a microcontroller as a mechatronical system component, to understand programming and interfacing issues, and to apply all these skills to the design of mechatronical systems and intelligent products (Yamazaki & Miyazawa, 1992; Minor & Meek, 2002; Mortensen & Hinds, 2002; Brazell et al, 2006; Bolton, 2006; Habib, 2008).

Transdisciplinarity as understanding (top-down approach), learning and practicing (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; 2002). There are four pillars of the transdisciplinary knowledge: learning to know, learning to do, learning to be and learning to live with other people (Delors, 1996). To learn and to understand are the most two important issues of the transdisciplinary mechatronical knowledge in the integrative process through modelling and control in the design of mechatronical systems. To achieve knowledge in the transdisciplinary mechatronical context, it is necessary to reconfigure the framework of the way the four pillars of transdisciplinary knowledge are working, for this reason they are put together, in a new framework, learning as achieving information and knowledge, as an objective rational extrinsic logical issue, and understanding as an ethic-semantic issue, the subjective relational dimension of knowledge. „Learning to learn to know by doing" and „learning to understand to be by living together with other people" is the multiple transdisciplinary paradigm, working as guidelines to achieve both necessary integrative semiophysical skills in a synergistic communicational context, through the 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 & Veres, 2010; Pop, 2008). Every pillar of transdisciplinary knowledge can be integrated in this framework to explain the mechatronical perspective of achieving knowledge in the informational knowledge based society with a new transdisciplinary mechatronical epistemology, a new creative logic of the included middle and a new mechatronical ontology. Learning to know becomes a ring of the extrinsic active knowledge chain, with "what, how and why" epistemic questioning paradigm (Harashima et al, 1996; Bradley, 1997; Buckley, 2000; Pop, 2008a), 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) (see fig.1). The ring "by doing", of the extrinsic active knowledge chain 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, 2002). Learning by doing could be, in the transdisciplinary approach of mechatronics, an apprenticeship in creativity (Siegwart, 2001), discovering what is new, bringing in actuality as innovation the creative potentialities, generating the conditions for the emergence of the authentic person, working at the top level of the creative potentialities (Boden, 1994; Waks, 1997). The intrinsic reactive approach of the mechatronical transdisciplinary knowledge, the learning to understand involves the spiritual dimensions of the knowledge process without which the knowledge couldn't be understandable (Nicolescu, 1996; Reason, 1998). The first step is "learning to be", a permanent communitarian apprenticeship in which teachers inform the disciples, as much as disciples inform the teachers, in a continuous teaching-learning process, so that the shaping of a person passes inevitably through a transpersonal dimension with fundamental tensions between the rational approach and the relational approach, discovering the harmony or disharmony between individuals and social life, testing the foundations of the personal believes in order to discover that which is found underneath, questioning in a scientific spirit being a precious guide for all the people (Nicolescu, 1996; 2002 ; Berte, 2003; 2005; Pop & Vereş, 2010). This can be done only by living together with other people in communion, supposing that the transgresive attitudes can, and must to be learned, allowing to a better understanding of own culture, to better defend the personal and collective identity with all its components. 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 aspects) (Reason, 1998; Nicolescu, 2008; Pop & Mătieş, 2008a). So, transdisciplinary mechatronical knowledge, with its extrinsic active (learning to know by doing) and intrinsic reactive (understand to be by living with others) components can be presented in a new original manner. The rational knowledge process, by „learning to learn to know by doing" involves „creativity through adequateness and innovation (to know-what, how, why)", combined 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 relational knowledge process, by "learning to understand to be by living with other people", 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 & Mătieş, 2008a; Pop & Vereş, 2010). It is very important to know the way mechatronics does work as a synergistic synthesis process of achieving knowledge, by integrating these two isues, rational (by doing) and relational (by being) as branches of the informergy, a transdisciplinary integration of the mattergy (matter and energy) with informaction (information and intentional action) (Pop & Vereş, 2010).

The existing models for educational mechatronics (Grimheden & Hanson, 2003; 2005) consider mechatronics as an engineering discipline, working only from an interdisciplinary perspective, different from the known disciplinary identity through three didactical oppositions: exemplifying - representative selection (what), interactive – active communication (how) and functional contextual – formal legitimation (why). The stages represented are going from the disciplinary identity (1), through multi(pluri)disciplinarity, with old courses (2); the cross(inter)disciplinarity new courses (3), followed by the curriculum stage with new programs (4); the organizational stage with new organizations (5) and finally, the so named thematic identity of the mechatronical education stage (6). As it is presented in other papers (Fuller, 2001; Mittelstrass, 2004; Habib, 2007; 2008) the inter(cross)disciplinary stage is considered as a final stage, for the knowledge attendable level, or there is a confusing or a missunderstanding about the difference between the inter(cross)disciplinarity and the transdisciplinarity (Jantsch, 1972; Fuller, 2001; Mittelstrass, 2004). It is very clear, that the knowledge process can not be closed (De Gruyter, 1998; Nicolescu, 1998; 2008), mechatronics as a transdisciplinary system of knowledge being an open system (Berian, 2010), the structurative integrating process modelling considering the existence of the three levels of the integration of the knowledge, thematic - curricular, methodological and synergistic, with different stages, predisciplinary, monodisciplinary and codisciplinary at first level, multi(pluri)disciplinary at the second level and, very important, at the third level there are three stages, structural synergy - interdisciplinarity, functional synergy

– crossdisciplinarity, and generative synergy – transdisciplinarity (Everitt & Robertson, 2007; Pop & Vereş, 2010).

Is proposed an integrative transdisciplinary model (Pop & Mătieş, 2008) which tries to demonstrate that mechatronics cannot be considered as multi(pluri)disciplinary, inter(cross)disciplinary, nor a new discipline, neither a simple methodology, but a transdisciplinary approach of the knowledge in the informergic society, as is sustained through the semiophysical communicational contextual message model, as well (Pop, 2008a). The transdisciplinary knowledge integrative mechatronical model presents five stages of the evolution of the knowledge process from monodisciplinary to transdisciplinary, through codisciplinary, (multi)pluridisciplinary and (inter)crossdisciplinary (fig. 2) (Pop & Mătieş, 2009). This model of the mechatronical knowledge is considered more integrative then others model known, through the educational paradigm by its transthematic, with representative selection, interactive communication, functional legitimacy aspects (mechatronical epistemology) (Grimheden & Hanson, 2003; 2005), as a reflexive way of communication through design, modelling (the creative logic of the included middle) (Lupasco, 1987; Nicolescu, 1996) and a socio-interactive system of thinking, living and acting (mechatronical ontology).

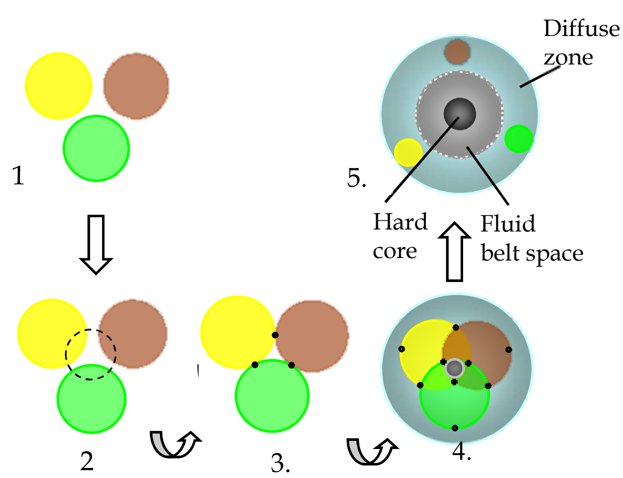

Fig. 2. The transdisciplinary knowledge integrative mechatronical model.

The three spheres represent different knowledge disciplinary fields of the mechanical engineering, electronic engineering and automation control engineering with computer engineeering systems) (Pop & Mătieş, 2008). Generally speeking, transdisciplinary knowledge integrative mechatronical model presented in fig. 2 could represent any synergistic context where two, three, or more disciplinary fields are working together in a generative - synergistic way, such as it is the semiophysics (phenomenological physics, semiotics, ethics) (Pop & Vereş, 2010), optomechatronics (optoelectronics, mechanics, informatics) (Cho, 2006), biomechatronics (biomechanics, electronics, informatics) (Mândru et al, 2008). Others such examples, the synergistic synthesis of Scientia (Mechatronical Education, as a new educational transdisciplinary paradigm, the mechatronical epistemology), of Techne (Mechatronical Technology, working as a reflexive way of the integrative design, the creative logic of the included middle), and of Praxis (Mechatronical Economy of the intelligent products, through the mattergic embedded informaction, with a new socio-interactive system of thought, living and action, the mechatronical ontology), are working in the same way. The common significant generative-sinergistic space of the knowledge resulted here is the Meta-Mecatronics (Phylosofia Technologica Systemica), considered as an open transdisciplinary integrative system of the informergic knowledge (Mieg, 1996; Wikander et al, 2001; Nicolescu, 2002; Grimheden & Hanson, 2001; Bridwell et al, 2006; Pop, 2009).

In the transdisciplinary knowledge integrative mechatronical model *the first stage* (1) represents the distinct *separation* between disciplines working with specific metodologies, thematic curricula and having net barriers, acting in a deapth competence approach in order to achieve knowledge. At the *second stage* (2), could be detected *a virtual connection* beween the knowledge fields with possible statistical transfer of the contents, methods, rules, definitions, preparing the next steps for the integrative process. *The multi(pluri)-disciplinary approach, cooperation through contact (3),* is characterized by different kinds of contacts between disciplines with radial mutual interactive flows through each contact point. A degree of competence in others disciplines is required, so in the multi(pluri)disciplinary research groups the individuals are working on related questions from different disciplinary perspectives sharing their expertise between them, the *inter(cross) - disciplinary approach, as a combination by overlapping (4),* with common creative - innovative spaces, with transfer of methods and content. Circular flows determine the emergence of a new systemic configuration in a paradigmatic way, a reflexive communicational language and a socio-interactive reorganization of the contents and methods, this kind of informational flow being prevalent. Inter(cross) - disciplinarity is a generic term for a plurality of activities that perform a range of functions with regard to disciplines, new fields, programs and projects, representing the situation where the main effort is to create inter(cross)disciplinary courses, being created new curricula suitable to the inter(cross) - disciplinary thinking and to the different identity of the subject. The structural synergistic stage is the interdisciplinary way of the integration of knowledge, as an application epistemological degree, with emergence of new disciplines at an organizational stage, with flexible borders, methods and with different ideas, themes and courses. When these flexible walls are penetrated, being possible to overpass the barriers, is talking about the synergistic functional stage, the crossdisciplinarity. The radial informational flows assure the fullfilment of the closed regions, which are growing from the initial points of contact to space filled with the separated elements and they are combining with the circular flows which become prevalent. Consequently are appearing new structures and new functions, with synergistic significance, with a new perspective, emerging as a necessity to reconfigure the inquiry space of the teaching - learning environment. In many cases, inter(cross) - disciplinary work can propel forward discipline - based work, designing structures that overcome the tension between disciplinarity and inter(cross)disciplinarity as a challenging task with different strategies appropriate in different contexts. Inter(cross) - disciplinarity is not a simple call for opening or overpass the borders between disciplines, the inter(cross) - disciplinary borrowings being tolerated and even appreciated for the value added to solve problems in one's home discipline, rather, the persistent need for inter(cross)disciplinary solutions to disciplinary problems brings out the inherently conventional character of disciplines (Pop & Mătieş, 2009).

While inter(cross)disciplinarity may not respect disciplinary boundaries ([19]), it needs own boundaries to protect its free-ranging activities, the goal of the inter(cross) - disciplinary integration tends to be even a simple realignment of disciplinary boundaries, or a flexible translation of them, in an adaptiveness context, realizing good communication skills, without loosing any vital information in the pursuit of a common research project (Wikander et al, 2001). Even researchers are engaged in more transient or intermittent inter(cross)disciplinary collaborations they communicate for the purpose of specialized multi-disciplinary courses and may remain within their discipline-based units, being required a combination of strategies to foster, support and recognize the equally important contributions of both disciplinarity and inter(cross) - disciplinarity. Only the University is able to recognize the differential extent to which these kinds of initiatives have temporal contingencies or issues of sustainability (Jantsch, 1972; Kaynak, 1997; Wikander et al, 2001; Castells, 2001; Fuller, 2002; McGregor & Volcksmann, 2010). From this inter(cross)disciplinary point of view mechatronics could be considered only as yet another technological discipline, an evolutionary discipline with a curricula and specific organizational patterns and courses, while nothing is said about the next possible step, that of the transdisciplinary way of achieving knowledge in mechatronics, the evolution being considered as finished (Yamazaki & Miyazawa, 1992; Grimheden & Hanson, 2003; 2005; Habib, 2007; 2008). Consequently, the closed regions are growing from the initial points of contact to space filled with the separated elements (fulfilling the fields), so the last level of integrative, as *a transdisciplinary approach by synergistic generative synthesis (5)* emerges in a new transdisciplinary informational-functional structure, with ethic-semantic values, including the spiritual dimension (bridging the gaps). This system has a central hard synergistic core with flexible, deformable and penetrable boundaries, surrounded by a "fluid belt" through which are captured and modulated 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 an integrative synergistic generative space, emerging a hierarchic-heterarchic rebuilding of the contents (could be just new transthematic disciplines as robotics, optomechatronics, biomechatronics, etc) (Cho, 2006; Hyungsuck, 2006; Mândru et al, 2008). The nodal points (inner, medium and outer) are considered as possible channels, knowledge search windows for explanation of the transdisciplinary mechatronical educational paradigm, through the specific creative innovative reflexive language of design, modeling prototyping, to create the socio-interactive way of understanding and practicing the mechatronics as a living, acting and thinking new lifestyle from the fourth wave perspective of knowledge, that of the informergic integration knowledge, functioning as a continuous synergistic integration of the knowledge as Science, Techne and Praxis (Pop & Vereş, 2010). If in the inter(cross)-disciplinary stage circular flows of knowledge are prevalent, in the transdisciplinary context there is a possible radial anisotropy of attractive-repulsive combining flows. In the transdisciplinary context is prevalent the radial anisotropy of attractive - repulsive combining flows, combined with inter(cross) - disciplinary circular flows of knowledge.

The presented transdisciplinary model for mechatronics give a better explanation then the existent models of the emergence of mechatronical epistemic teaching-learning paradigm, that of the synergistic identity of mechatronics, as a new transthematic generative discipline ([20]) (Pop & Mătieş, 2008; Berian, 2010). In this way it is possible to explain the appearing of the bridges between the different disciplines, as a step by step way through codisciplinary connection, multi(pluri)disciplinary combination, inter(cross)disciplinary overlap and transdisciplinary synergistic synthesis (De Conink, 1996; Klein, 2002; Mittelstrass, 2004; Choi & Pak, 2008). Due to the radial centripetal flows new mechatronical disciplines (optomechatronics, robotics, biomechatronics, etc) are emerging as satellites in the outer diffuse space, where the „codisciplinary outer nodal points"([21]) are working as a resource spring generating mechatronical knowledge, expressed as a synergy between mechatronical transdisciplinary education, mechatronical design as a reflexive creative language and the mechatronical intelligent systems, technologies and products. The transdisciplinary perspective on mechatronical way of achieving knowledge gives the openness to a better understanding of the world from the mechatronical informergic (informaction as intentional action & information, and mattergy as energy incorporated in matter) integration process in the knowledge based society (Gitt, 1997; Pop & Vereş, 2010).

2.3 The mechatronician, a new synergistic job profile

Education and training with specific procedures and techniques are crucial in continuously economic and social changes, cultural differences and similarities concerning teaching/learning process and collaboration styles being present even not sufficiently integrated yet into curricula, courseware and teaching methods (Yamazaki & Miyazawa, 1992; Lyshevski, 2000). One of the transdisciplinary way to achieve knowledge in the mechatronical context is the Problem-Based Learning (PBL) method, working together with other active learning models, such as: *group work*, *guided design*, *work-based learning*, *learning by doing* and *case studies, learning by discovery,* being distinguished from these by solving a complex and realistic problem (Altshuller et al, 1989; Barret, 2005; Boud & Feletti, 1991; Fink, 2002; Grinko, 2008; Savary, 2006). The basic ideas behind Problem Based Learning are active learning, constant assessment, emphasis on meaning and not on facts, freedom and responsibility, access to resources. The work is organized in projects, small groups of disciples and guiders (instructor, teacher, mentor, facilitator) meeting together to discuss about a case, getting solutions in a creative-innovative framework, where the project aims working towards to solve a particular problem in a learning environment. The framework is characterized by a large responsibility of the disciples and teachers, as well, having a cognitive coaching role instead of a lecturing one, the disciples receiving from the guide an initial guiding plan-work (as a scenario), then they question the guide to get any additional information to solve the problem (Boud & Feletti, 1991; Barret, 2005; Savary, 2006). The computers have to be used as tools to provide alternative sources of learning material, interactive learning situations and simulation of systems that cannot be used in reality for reasons of cost, size or safety, including the Internet as the greatest source of information available for learning, as well as simulation tools with a number of benefits to education, available in industry. It is interesting to know how much of real experience can be replaced by learning with simulations, but is demonstrated that only the use of the computer simulations cannot replace all forms of applied training, in many branches of the science and technology-oriented programs hands-on activities in laboratories and workshops remaining an indispensable constituent of effective learning. Flexibility and adaptability should be characteristics most important to determine tertiary education ability of the institutions to contribute effectively to the capacity building needs of developing knowledge achievement skills and to react swiftly by establishing new programs, reconfiguring existing ones, to eliminate outdated courses without any administrative obstacles, in the context of systematic efforts to develop and implement a vision through strategic planning, by identifying both favorable and harmful trends in their immediate environment and linking them to a rigorous assessment of their internal strengths and weaknesses, so the institutions could better define their mission, market niche and medium-term development objectives and formulate concrete plans to achieve these objectives (Lyshevski, 2000; Pop, 2009a). To face effectively the challenges of economic development within a global marketplace, the new generation of engineering professionals has to be educated in a new framework, as a continuum educational program, to develop and strengthen the integrative skills in analysis, synthesis, and contextual understanding of problems and also, to expose them to the latest technologies in different engineering fields and the implications for sustainability of their use. The problem-based learning (PBL) approach, open-ended design problem solving by a multi(pluri)disciplinary team of disciples in a transdisciplinary context, simulation, modeling, prototyping, are integrated alltogether with the technology, economics, ecology and ethics, as four dimensions of the sustenability ([22]), considering them as parts of a synergistic - generative approach of knowledge integration (Grinko, 2008; Bras et al., 1995; Pop, 2008). Problem-based learning (PBL) is a contextualized approach to schooling, being centered to the disciples, where learning begins with a problem to be solved together, rather than mastering individually different contents of the research themes, courses, laboratory experiences (Grimheden & Hanson, 2003). PBL is based on the notion that learning occurs in problem-oriented situations is more likely to be available for later use in those contexts (Bras et al, 1995). PBL includes among its goals the developing of the scientific understanding through real-world cases; the reasoning strategies and the self-directed learning strategies. In PBL the focus is on what disciples learn, but more important becomes the way the knowledge could be applied, maintaining a balance between theory and practice (top-down in balance with bottom-up approach). The learning team (disciples) is evaluated by the teaching team (instructors), resulting a better coverage of specific problems, the results and experience of the research activity carried out by the teachers could be incorporated in the educational and training programs for disciples. Both, PBL and TT methods lead to more self-motivated and independent disciple, these learning methods preparing better the disciples (students, apprentices, pupils, adults, as well) to apply their learning to real-world situations (Mândru et al, 2008).

An alternative complementary method to PBL and TT is TRIZ (theory of inventive problem solving). The main point of this method is the observation that good ideas/solutions have the properties to resolve contradictions, to increase the "ideality" of the system and to use idle, easily available resources. To solve a technical problem has to find the contradiction in the definition of the problem, identifying it using available resources to arrive at the ideal final solution as closely as possible, choosing the good context, methods and the best possible way (Altshuller et al, 1989). All innovations emerge from the application of a very small number of inventive principles and strategies, technology evolution trends being highly predictable. The strongest solutions transform the unwanted or harmful elements of a system into useful resources, and also actively seek out and destroy the conflicts and trade-offs most design practices assume to be fundamental. TRIZ revolves around finding contradictions and using the collected knowledge and experience of decades is able to solve the problem. Universities and vocational training schools with their links to industry are under an increasing pressure placed on them to expose disciples to real working environments in education and training of multi-skilled technicians leading to a new type of job profile which contains a mix of electrical, mechanical and IT knowledge, a mechatronical one, to be trained for implementation and service using the education and training of engineers for design and manufacturing of mechatronical devices (Wikander, Torngren &

Hanson, 2001; Bruns, 2005; Mătieş et al, 2005). To get expertise as a vital and dynamic living treasure many enterprises rely on formal learning (off-the-job training), but the informal learning (on-the-job training) can be more close to the problems to be solved, being organized in a cooperative way, crossing the borders between different professions that are involved in a project (Jacobs & Jones, 1995). Experts work in projects (small groups of different professions) to solve problems, learn how to learn and think critically, learn how to understand, identifying the skills needed to meet the requirements emerged (bottom-up learning-teaching) and developing a personal theory of management, leadership or empowerment (top-down teaching-learning).

The design cycle for the intelligent products often take place in a competitive environment, where following the trends in technology itself and responding to innovative solutions from competitors create a challenging road for the engineering development process. Within this rapidly changing medium products, processes or systems need to be designed and developed satisfying both the customers and the developers. Web-based virtual laboratories, remote experience laboratories and access to digital libraries are some examples of the new learning enhancing opportunities to increase connectivity. In this context, tertiary institutions with virtual libraries can join together to established, inter-library loans of digitized documents on the Internet to form virtual communities of learning helping each other to apply and enrich available open education resources with significant challenges. In this way could be created a more active and interactive learning environment, called "instructional integration" with a clear vision to develop and create the new adequate technologies and the most effective way to integrate them in the design programs and delivery (Bridwell et al., 2006). Combining online and regular classroom courses gives to disciples more opportunities for human interaction, and developping the social aspects of learning through direct communication, debate, discussion in a synergistic communicational context (Pop, 2008). These requirements are applied also to the design and delivery of distance education programs which need to match learning objectives with appropriate technology support. The new types of distance education institutions and the new forms of e-learning and blended programs meet acceptable academic and professional standards, but a poor connectivity is a serious constraint in the use of the informational control technology related opportunities, with their limitations (Furman & Hayward, 2000). The use of simulation tools has a number of benefits in education, because the disciples are not strictly related with real world, and at the same time is able to explore a range of possible solutions, easily and quickly, with tools available in industry, with significantly less costs than the real world components and allows more participation and interaction than a limited demonstration. But, it is very clear that real experience can not be replaced by learning with simulations, being necessary to use complementarly, the virtual tools as design, modelation, simulation and real and the real world representations as prototyping, building smart mecahatronical products (Bridwell et al, 2006; Giurgiutiu et al., 2002). Only computer simulations cannot replace all forms of applied training, but in many branches of the science and technology-oriented programs hands-on activities in laboratories and workshops remain an indispensable constituent of effective learning. Flexibility and adaptability should be characteristics most important to determine tertiary education ability of the institutions to contribute effectively to the capacity building needs of developing knowledge achievement skills and to react swiftly by establishing new programs, reconfiguring existing ones, to eliminate outdated courses without any administrative obstacles, in the context of systematic efforts to develop and implement a vision through strategic planning, by identifying both favorable and harmful trends in their immediate environment and linking them to a rigorous assessment of their internal strengths and weaknesses. In the disciplinary educational system there is obvious the lack of flexibility and low level of adaptation to the changing conditions of the environment. A theoretical framework for this didactics requires more insight into how individual learning styles use individual learning methods, techniques and technologies, to outline paths to develop meaning and concepts from basic experiences with natural and technical phenomena, being important to analyze the transitions between concrete and abstract models of production systems and to specify abstract solution for an automation problem by a concrete demonstration (Schäfer, 1997; Bruns, 2005). To fulfill the demands for multi-skilled technicians and skilled workers vocational training schools together with industry are confronted with the need to develop theoretical integrated with practical learning sequences. Tasks and problem solving in mechatronics requires cognitive, operational knowledge and practical experience about building systems, diagnosis and maintenance techniques, a significant challenge being that these tasks are essentially characterized by the use of tele-medial systems, in a synergistic communicational networking system (Palmer, 1978; Grossberg, 1995; Arecchi, 2007; Baritz et al, 2010). To meet these requirements in education and training it has to elaborate concepts concerning pedagogical, technical and organizational aspects in a new significant synergistic way, that of the transdisciplinary educational paradigm (Pop, 2008; Pop & Maties, 2008) with *holistic-synergistic* problem solving or tasks distributed over time of training with increasing requirements to the learners, in a logical-creative framework, through included middle and lateral thinking (Lupasco, 1987; Waks, 1997; de Bono, 2003). Through this new didactical tansdisciplinary concept is avoided the disciplinary distribution of learning contents into separate classes for different separated disciplines, whereas the learners had been left alone to find out the connections between these contents. It has to be fulfilled every one of the four didactical principles in the transdisciplinary field of mechatronical training paradigm: synergistic transthematic identity, vertical exemplificative selection, interactive creative participation-communication and contextual functional legitimacy (Grimheden & Hanson, 2003; 2005; Berian 2010).

3. Conclusions

Mechatronics and transdisciplinarity are presented as multiple integrative possibilities to understand the way to achieve, transfer and incorporate knowledge in the context of the informergical knowledge based society. In order to know the way mechatronics does work in the transdisciplinary methodological approach it is very important to understand the new sinergistic-generative transdisciplinary model about the perspective of the integration from the thematic-curricular monodisciplinary level to the synergistic one, as structural, functional and generative stages, passing through methodological level.

The transdisciplinary knowledge search window, as a new methodology is working complementarily with the top-down and bottom-up levels of knowledge, integrating the rational knowledge of things expressed by „learning to learn to know by doing" with relational understanding of the world, working by „learning to understand to be by living together with other people". This multiple transdisciplinary paradigm ([23]), is integrating informergically (informaction integrated in mattergy) the creativity (adequateness and innovation) in action (competition and performance) and authenticity (character and competence) through participation (apprenticeship in communion).

Only the transdisciplinary knowledge achievement, as a new methodology, can explain the way the creativity, with a synergistic signification, works as an intentional action through ideas, design, modelling, prototyping, simulation, incorporating informergically the inform-action in matt-ergy, to realize smart products, sustainable technologies and specific integrative methods to give solution to the emerging problems. Real experiences cannot be replaced by learning only with simulations, for this being necessary to use complementarily, the virtual tools as design, modelling, simulation and the real world representations as prototyping, building smart mechatronical products, technologies and systems.
The proposed integrative model demonstrates that mechatronics cannot be considered as multi(pluri)disciplinary, inter(cross)disciplinary, nor a simple new discipline, neither a simple methodology, but a transdisciplinary approach of the mechatronical knowledge in the informergical society (informergy is informaction incorporated intelligently in mattergy), as is sustained through the semiophysical communicational contextual message model, with the "What-How-Why" questioning paradigm ([24]) of the mechatronics. The transdisciplinary knowledge integrative mechatronical model, with the five stages of the evolution of the knowledge process from monodisciplinarity to transdisciplinarity, through codisciplinarity, multi(pluri)disciplinarity and inter(cross)disciplinarity, is considered more integrative then the educational mechatronical model, integrating the transthematic aspect of the mecahatronics, with representative selection, interactive communication and functional legitimacy aspects (mechatronical epistemology), as a reflexive way of communication through design, modeling (the creative logic of the included middle) and a socio-interactive system of thinking, living and acting (mechatronical ontology).
The most important thing is to know what mechatronics is, what isn't and how does it work, mechatronics being not a simple discipline, but working through the new transdisciplinary transthematic educational paradigm by its exemplifying selection (what), interactive communication (how) and functional contextual legitimation (why) aspects.
Mechatronics can be considered as a synergistic integrative system of Scientia, as a new educational transdisciplinary paradigm (mechatronical epistemology), of Techne, working as a reflexive way of the integrative design (the creative logic of the included middle) and, as Praxis, through a new socio-interactive system of thought, living and action (mechatronical ontology)
About the future of integrative mechatronics, the transdisciplinary approach opens new perspectives on its development, incorporating more and more ideas which will be accounted to improve the way to do things and to live in the new context of ever-changing needs and willings of a complex and complicated world, when innovations and technologies have to be improved and developed with the rapidly changing times. The postepistemic economy will integrate in a synergistic-generative way the technical dimension with epistemic and with socioeconomical dimension, resulting the metamechatronics as a transdisciplinary engineering mecha-system ([25]).

4. Notes

[1]Synergy, synergistic signification is the transdisciplinary semiophysical process by which a system generates emergent properties resulting in the condition in which a system may be considered more then the sum of its parts (equal to the sum of its parts and their relationships) (synergy, $1 + 1 > 2$, more then everyone, and signification, $1 - 1 \neq 0$, otherwise then everyone) (Tähemaa, 2004; Bolton, 2006; Pop & Vereş, 2010).

[2]Agents are considered to be the ocupants of a knowledge system field (a semophysical system working through spatial participative sequence - space wise, temporal-connective sequence – time wise, actional – interactive sequence – act wise) (Pop, 1980);
[3]This a contextual adaptation of the apo-kataphatic approach of knowledge which does explain through the interparadigmatic dialogue the japanese roots of the mechatronics (Mushakoji, 1988).
[4]Principle of included middle (tertium quid) is the natural law by which triple is produced out of couple, rejecting the claim that the the mind (consciousness) and the body (object) are separated. Is proposed a change to the third classical linear logic axiom, submitting that a third term T does exist, being simultaneously A and non-A. Only considering this third term T, problem solvers would be able to integrate perspectives from different realities (economics with environmental), let alone integrate Subject (consciousness and perceptions) with Object (information) (Nicolescu, 2011).
[5] Smart mechatronical products, technologies and systems are considered sustainable if they are incorporating transdisciplinarily the informaction (information in action) in mattergy (matter and energy), with a high level of reciclable matter and low level of incorporated energy, in a modular configurational design, with a creative and responsible stewardship of resources in order to generate stakeholder value contributing to the well-being of current and future generations (Rzevski, 1995; Montaud, 2008).
[6]Paradigm is a set of fundamental beliefs, axioms, and assumptions that order and provide coherence to our perception of what is and how it works (a basic world view, also example cases and metaphors), refering to a thought pattern in any scientific discipline or other epistemological context, with theories, laws, generalizations and the experiments performed (*broadly, a philosophical or theoretical framework of any kind)* (Pop & Vereş, 2010);
[7]Mechatronician is a multi-skilled specialist, as engineer, technician, worker, envolved in the mechatronical design, creation and maintainance of smart products, technologies, systems (Rainey, 2002);
[8]The multi(pluri)disciplinary approache juxtaposes disciplinary/professional perspectives, adding breadth and available knowledge, information, and methods, speaking as separate voices; such activities involve researchers from various disciplines working essentially independently, each from own discipline specific perspective, to address a common problem; even multi(pluri)disciplinary teams do cross discipline boundaries; however, they remain limited to the framework of disciplinary research; Multidisciplinarity – a relationship between related disciplines occurring simultaneously without making explicit possible relationships or cooperation between them, working at methodological level of the integrative process of knowledge; Pluridisciplinarity – a relationship between various disciplines grouped in such a way as to enhance the cooperative relationships between them, working at the methodological level of the integrative process of knowledge (Pop & Mătieş, 2008);
[9]Inter(cross)disciplinarity is working on unity of knowledge differing from a complex, dynamic web or system of relations, but without producing a combination or synthesis which would go beyond disciplinary boundaries, for innovative solutions to knowledge questions, remaining in the disciplinary bounderies. Interdisciplinarity is a structural synergistic approach for a group of related disciplines having a set of common purposes and coordinated from a higher purposive level, that integrates separate disciplinary data, methods, tools, concepts, and theories in order to create a holistic view, or common understanding of complex issues, questions, or problem. Crossdisciplinarity is a functional

synergistic approach for various disciplines where the concepts or goals of one are imposed upon other disciplines, thereby creating a rigid control from one disciplinary goal (Habib, 2008, Pop & Mătieş, 2009, Fuller, 2001).

[10]Transdisciplinarity concerns with that is at once between the disciplines, across the different disciplines, and beyond all disciplines, connecting what is known (theory - what) to action (application - how), in order to accomplish specific goals in the context of human survival, sustainability and creativity (worldly problems and/or opportunities), creating new knowledge, new languages, new disciplines, new systems, new processes and new economic opportunities. Transdisciplinary approaches are comprehensive frameworks that transcend the narrow scope of disciplinary world views through an overarching synergistic generative sinthesis of knowledge, including cooperation within the scientific community with a permanent debate between research and the society at large, transgressing boundaries between scientific disciplines and between science and other societal fields, with deliberation about facts, practices and values, at the stages of conceptualization, design, analysis, and interpretation by integrated team approaches, realizing the coordination of disciplines and interdisciplines with a set of common goals towards a common system purpose (Jantsch, 1972; Nicolescu, 1996; Max Neef, 2005).Transdisciplinary methodology is working with three axioms, the ontological axiom (there are different levels of Reality of the Object and, correspondingly, different levels of Reality of the Subject); the logical axiom (the passage from one level of Reality to another is insured by the logic of the included middle) and the epistemological axiom (the structure of the totality of levels of Reality has a complex structure, every level being what it is because all the levels exist at the same time) (Nicolescu, 1996).

[11]Predisciplinarity stage is the first step of the lowest level, the thematic-curricular level of the integration knowledge process, the way a discipline is born; disciplinarity context is the classical mode of deapth approach of knowledge with own boundaries, methodologies, and specific content; codisciplinary context of the integration of knowledge is conecting, from a transdisciplinary point of view, the three levels, the thematic-curricular, the methodological level and the synergistic one (Pop & Mătieş, 2008).

[12]Communities of practice (CoPs), as knowledge achievement environments, are functioning as creative group of people who share an interest, a craft, and/or a profession, evolving naturally because of the common interst of the members in a particular domain or area, or it can be created specifically with the goal of gaining knowledge related to their field (Wenger & Snyder, 2000).

[13]Organisational educational environment is working with the principles of mechatronical education which can be applied successfully to all teaching levels, creating the necessary teaching-learning environment, as a teaching factory, as a mobile mechatronical platform, or as another specific educational systems (Nonaka & Takeuchi, 1994; Lamancusa et al, 1997; Doppelt & Schunn, 2008; Mătieş, 2009).

[14]Cognitive way of knowledge does explain the way stimuli (coming from the sensitive sensors, as a bottom up approach) and signals (at the brain level, as a top down approach) are working together in the ART (Adaptive Resonant Theory) (Grossberg, 1995);

[15]Creative innovative context is determined by the learning/teaching transdisciplinary environment, as teaching factory through all life learning aspects (lifewide learning, longlife learning and learning for life), that challenges perspective of the learners and facilitates the expansion of their worldview, promoting human fulfillment, enabling the learners to cope with uncertainty and complexity, empowering them to shape creatively change in order to

configurate the future through the synergistic design (Lamancusa et al, 1997;Alptekin, 2001; Erdener, 2003; Habib, 2008).

[16]Transdisciplinary semiophysical contextual message model is working with 7 questions: where (space wise sequence), when (time wise sequence), who, with whom, what, how and why (act wise sequence) (Bradley, 1997; Harashima et al, 1996; Buckley, 2000; Pop & Vereş, 2010).

[17]Knowledge search window is a methodological concept explaining the bottom-up/top-down mechanism of the teaching-learning process in the mechatronical educational paradigm using the included middle transdisciplinary perspective (Lupasco, 1987, Pop, 2009);

[18]Conceptual space presuposes to identify, to develop and to evaluate the creativity working in such a way to realise the equillibrium between tradition and innovation, the most creative individuals being considered those who explore a conceptual structure going beyond them in a transdisciplinary way, managing the reconfiguration of the new structures to achieve knowledge which transgress the barriers, bridging the gaps and filling the fields (Boden, 1994; Schafer, 1996;De Vries, 1996; Doppelt & Schunn, 2008).

[19]Boundaries are parametric conditions that are delimiting and defining a system, and set it apart from its environment;

[20]Mechatronics works as an opening new transthematic generative discipline, with a very transdisciplinary character, bridging the gaps between different disciplines, as a step by step way through codisciplinary connection, multi(pluri)disciplinary combination, inter(cross)disciplinary overlap, and transdisciplinary synergistic synthesis (Pop & Vereş, 2010);

[21]Codisciplinary outer nodal points are considered as resource springs generating mechatronical knowledge, expressed as a synergy between mechatronical transdisciplinary education, mechatronical design as a reflexive creative language and the mechatronical intelligent systems, technologies and products (Pop & Mătieş, 2008);

[22]Sustainability represents the creative and responsible stewardship of resources (human, natural and financial resources management) in order to generate stakeholder value while contributing to the well-being of current and future generations of all beings. Sustainable development is an individual, societal, or global process, which can be said to be sustainable (sociocultural, economical, educational, technological, and ecological as well) if it involves an adaptive strategy that ensures the evolutionary maintenance of an increasingly robust and supportive specific environment, such a process enhancing the possibility to generate a wellfaire state (Giovannini & Revéret, 1998);

[23]Multiple transdisciplinary paradigm represents the informergically integration (informaction integrated in mattergy) of the creativity (adequateness and innovation) in action (competition and performance) and authenticity (character and competence) through participation (apprenticeship in communion) (Pop & Mătieş, 2009).

[24]The "What-How-Why" questioning paradigm is a transdisciplinary knowledge integrative mechatronical model, integrating the transthematic aspect of the mecahatronics, with representative selection, interactive communication and functional legitimacy aspects (mechatronical epistemology), as a reflexive way of communication through design, modeling (the creative logic of the included middle) and a socio-interactive system of thinking, living and acting (mechatronical ontology) (Pop & Vereş, 2010).

[25]Meta-mechatronics is a transdisciplinary engineering mecha-system, resulting through synergistic synthesis of the Scientia (Educational Mechatronics), Techne (Technological

Mechatronics), and Praxis (Economical Mechatronics) at the top level of integration as informergical metamodel (Hug et al, 2009; Pop & Vereş, 2010).

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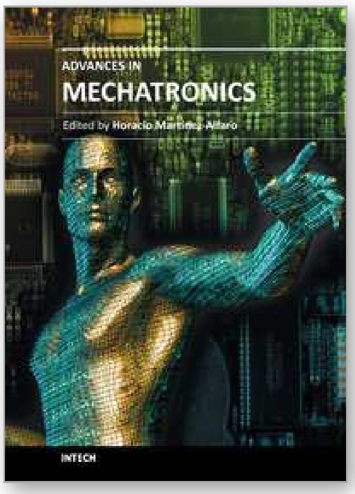

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Numerous books have already been published specializing in one of the well known areas that comprise Mechatronics: mechanical engineering, electronic control and systems. The goal of this book is to collect state-of-the-art contributions that discuss recent developments which show a more coherent synergistic integration between the mentioned areas.Â Â The book is divided in three sections. The first section, divided into five chapters, deals with Automatic Control and Artificial Intelligence. The second section discusses Robotics and Vision with six chapters, and the third section considers Other Applications and Theory with two chapters.