Transdisciplinarity, Mechatronics and Organizational Learning

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This paper presents details related on the fundamental approaches for transdisciplinarity learning, based on the innovative potential of mechatronics and the concept of organizational learning. Mechatronics, the result of integration of mechanics - electronics and informatics is the technology of the 21st century. It is the science of intelligent machines and environment for smart education and organizational learning in the knowledge society too. Mechatronics, through its integrative,sinergic character, is an open field that transcends the limits of a single discipline.The mechatronic identity based on the complexity concept is trans-thematic one. The basic elements about Romanian national platform for smart education and organizational learning are outlined too.

Keywords*:* Transdisciplinarity; mechatronics; education;integration complexity; organizational learning.

1 Introduction

The evolution of the society development is closed related on the technology development. It is relevant if the limits are mentioned: the stone technology-mechatronic technology. The shift in the society development from one stage to another was caused by revolutions. As we know, in the literature are mentioned: material revolution, energy revolution, quantum revolution, information revolution and mechatronic revolution [12, 25].

Stephen Hawking, English theoretical physicist said, the 21st century will belong to complexity [1,2]. The complexity is closely related on the idea of non - separability, which “seems to be a fundamental principle of all that is profound in the world” [1, 2].

Consequently, research and education of the future must be shaped by the force lines of complexity and non-separability. So that, in that context to be transdisciplinary is a major need. Of course, for that we must learn transdisciplinarity[1, 2, 19, 25].

On the other hand, Russell Ackoff one of the pioneers and promoters of the systemic thinking concept underlines that effective research is not disciplinary, interdisciplinary, or multidisciplinary it is transdisciplinary.

Systems thinking is holistic, it attempts to derive understanding of parts from the behavior and properties of wholes, rather than derive the behavior and properties of wholes from those of their parts. Disciplines are taken by science to represent different parts of the reality we experience.

But disciplines do not constitute different parts of reality; they are different aspects of reality, different points of view. Any part of reality can be viewed from any of these aspects. The whole can be understood only by viewing it from all the perspectives simultaneously. The separation of our different points of view encourages looking for solutions to problems with the same point of view from which the problem was formulated.

The last three revolutions marked the XXth century. As Quoting Einstein: “Without changing our pattern of thought, we will not be able to solve the problems we created with our current patterns of thought.” When we know how a system works, how its parts are connected, and how the parts interact to produce the behavior and properties of the whole,we can almost always find one or more points of view that lead to better solutions than those we would have arrived at from the point of view from which the problem was formulated. For example, we do not try to cure a headache by brain surgery, but by putting a pill in the stomach. We do this because we understand how the body, a biological system, works. When science divides reality up into disciplinary parts and deals with them separately, it reveals a lack of understanding of reality as a whole, as a system (Russel Ackoff).

Systems thinking not only erases the boundaries between the points of view that define the sciences and professions, it also erases the boundary between science and the humanities. Science consists of the search for similarities among things that are apparently different; the humanities consist of the search for differences among things that are apparently similar. Science and the humanities are the head and tail of reality–viewable separately, but not separable.

In the context, it is easy to understand that: “Promoting the complex and transdisciplinary thinking in structures, programs and areas of influence of the University, will enable the progress towards its mission forgotten today – the study of universality” [13, 14, 15].The basic problems for transdisciplinarity learning are: the system thinking development; team work/learning; organizational learning; integral education concept promotion; the integration-complexification process in the nature, technology and society understanding; the role of information in the integration complexification process: information carriers, information link, information kinematic chain, information field, sensitive information etc. The above details are in fact the main features of the smart people, the result of the smart education. As we know smart/intelligent people, intelligent management and intelligent technologies are the main pillars of the smart cities/communities [12, 25, 28].

Based on the world experience in the field of mechatronic technology and education and national experience of more than a quarter of century, in the paper are outlined solutions for the above-mentioned problems, based on valorization the innovative potential of mechatronics.

2 Mechatronics, the Technology of the 21st Century

2.1 Mechatronic Concept

The mechatronic word, patented by Yaskawa Electric Concern in Japan at the beginning of the eighth decade of XXth century, was used to describe the technological fusion of three major engineering fields: mechanical- electrical, electronics- automation, computer science. [10, 12, 17, 27]. All high-tech products are mechatronic ones. Some representative examples are: the modern automobile, the CNC machines, the computing technique, the telecommunication technique, the research equipment, the robots, the biomedical apparatuses, the electro-household appliances etc. Practically, mechatronics is present in all fields of activity, including agriculture and construction.

The evolution in technological development has led to the emergence of mechatronics. This development is suggestively highlighted in Figure 1. [3, 4, 10, 12].

The mechanical technology developed towards mechanization is the backbone of mechatronics. The progress in the field of electronic technology, the emergence of integrated circuits, small, cheap and reliable, allowed the integration of electronics into mechanical structures. This is the first step towards integration: electromechanical integration.

The next step in integration was due to the emergence of microprocessors. Having the same constructional features as integrated circuits, microprocessors could be integrated into previously built electromechanical structures. Thus, they can retrieve information about their internal status and about the state

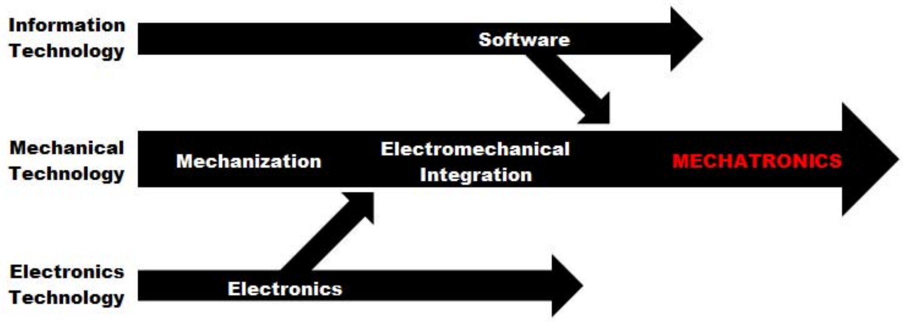

Figure 1: Technological flow towards mechatronic integration.

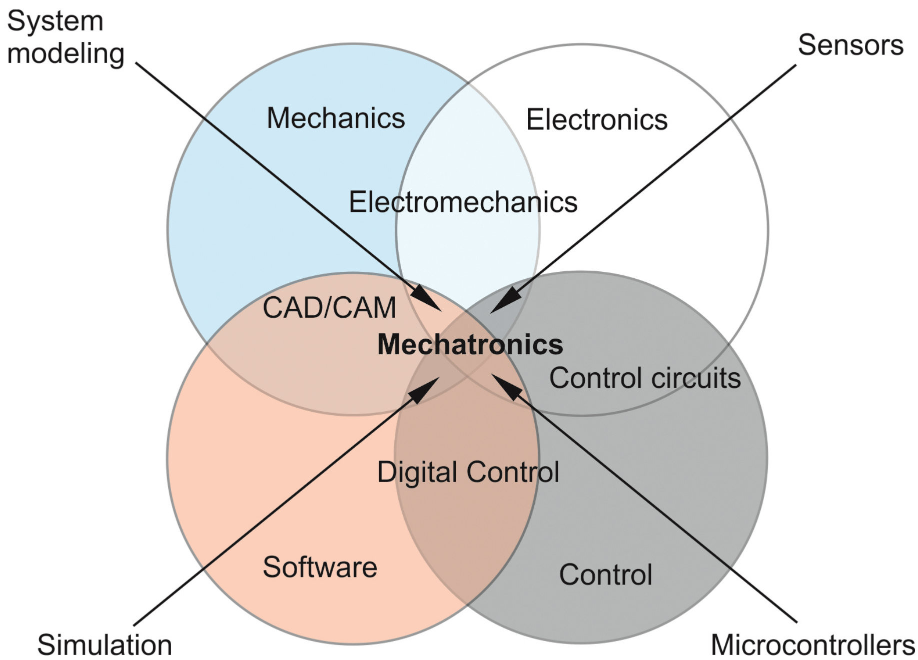

Figure 2: The mechatronics concept.

of the environment, process this information, and make decisions about how the system behaves.

The concept of mechatronics is highlighted in Figure 2. The scheme illustrates that the traditional, fragmented approach, based on which mechanical engineering studies specific problems of mass motion, is no longer possible in the conceptual work; electrical-electronics engineering studies specific electron motion issues, and the automation engineers, the computer scientists study the information motion specific issues. The three movements existing in the structure of a mechatronic product cannot be separated.

If in the traditional technology the basics are the material and the energy, in mechatronics these two elements are added a third tune-giving component, the information. This position of information in relation with material and energy is supported by the following arguments: [10, 11, 12, 17]:

- information ensures the satisfaction of the spiritual needs of man;
- only information ensures the increase of the added value of all things;
- information means culture.

Based on Figure 3, a comparative analysis of the three components of mechatronic technology can be made [10, 11, 12, 17]]. The analysis considers: the origin of the resources, the reserves, the demand and the meaning of life from the three elements' point of view. The analysis conclusions motivate the interest shown throughout the world to promote this technology. Certainly, the intelligent products

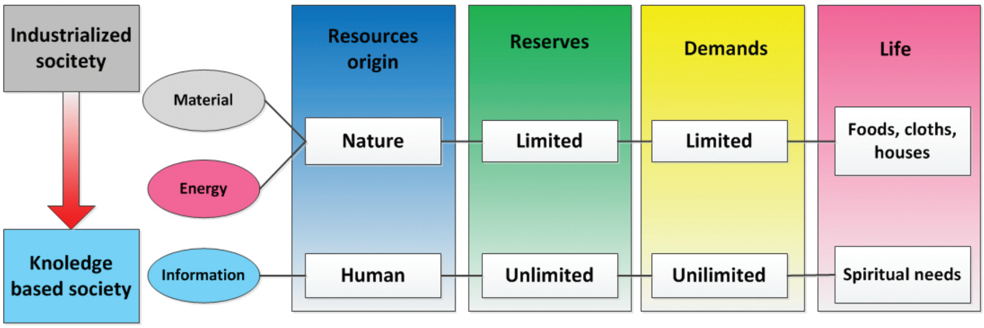

Figure 3: The relation between material, energy and information.

making (which incorporates a large amount of information) will increase their functional performance. On the other hand, material and energy resources are preserved in this way. But, by consuming less material and by processing less energy, the pollution decreases. Thus, there are other new valences of mechatronic technology: it is a non-dissipative and less polluting technology.

The integration of information links into the technical systems structure provides them with flexibility and reconfigurability [11, 12, 16, 20, 22].

The comparative analysis of the three elements of mechatronic technology reveals the determinant role of information in relation with material and energy. The value of information does not depend so much on quantity as it does on freshness, since human mind always demands new stimuli.

The value of material and energy depends on how it integrates, and the information value depends on differentiation. Mechatronic technology launched the challenge of sensitive information. The coaches' commercial value, for example, does not depend only on their technical performance. Style, color, design in general have an influence on passengers. Every machine transmits information that stimulates the senses of the human being.

The presence of information links in the structure of technical systems requires small quantities of material and energy; this implies an increase in the operating flexibility and efficiency. In this context, quantitative and qualitative information assessment is a major issue in education, research and technology. The signal is the means of physical manifestation of information. The signals are generated by sensors (artificial sensing organs) integrated into the structure of smart machines and systems.

The sensors materialize the perception function in the structure of an intelligent system. Microcontrollers materialize the brain functions and the actuators (the execution elements) are the artificial muscles. New concepts, both in education, research and technological development, such as: information carriers, information links, information kinematic chains, and information field [3, 4, 12, 18], have evolved in this context.

2.2 Mechatronic Education

The mechatronic principles in education focus on the systemic thinking developing, integrating and forming skills for teamwork. In the knowledge society, approaches to the development of systemic, integrative thinking are as important as writing and reading. The knowledge production results from the structuring and integration of information. Of course, the wealth of knowledge and the horizon of knowledge influence an individual's personality, but the ability to structure and integrate this information is predominant in defining the personality of the individual. The defining features of the market economy specialist are flexibility in action and thinking; these skills are formed through mechatronic education. Integrating information links into the structure of mechatronic systems gives them a defining feature, flexibility. In this context, mechatronics education meets the requirements of intelligent education, providing the necessary skills for pupils, students, adults etc. for intelligent integration, smart organizations, smart community etc. Organizations and communities become intelligent and therefore competitive, by learning. Competence is the bridge between man and organizations (institution) and beyond, between organizations and the community. Successful self-programming of individuals, organizations and communities' results in a qualitative participation on each level, with a positive impact

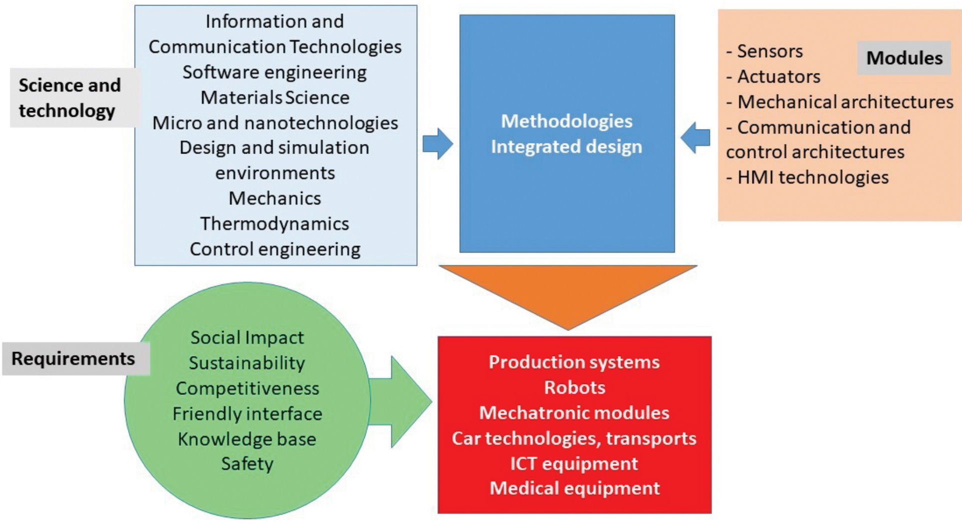

Figure 4: The integrated design concept.

on integrated elements [12, 25, 28]. In intelligent education environments the basic infrastructure by mechatronic platforms is provided. As complex technical systems, these platforms integrate into their structure elements of mechanical engineering (mechanisms, mechanical transmissions, etc.), electrical engineering elements (actuators, sensors, microcontrollers, filters, amplifiers, etc.) and control and informatics elements (control algorithms, dedicated software, human-machine interfaces etc. The specific structure of the mechatronic platforms facilitates the understanding of the integration-complexification process in nature and technology, as well as the role of information and information links in this process. The trans-thematic identity of mechatronics, based on the concept of complexity is argued in the works [1, 2,12, 19]. In this regard, we can say that the mechatronic platforms are the basic infrastructure for transdisciplinarity learning, with the aim of stimulating creativity and increasing labor productivity in the knowledge production. Mechatronic knowledge means technological knowledge, focusing on methods of producing intelligent systems, services and products [12, 19].

2.3 Mechatronics in Engineering Education and Practice

For the engineering practice, mechatronics marked the shift from traditional, sequential engineering to simultaneous, concurrent engineering. Therefore, the concepts of integrated design and design for control were developed. The details on the integrated design methodology are presented in the works [6, 11, 12, 20]. Thus, it is necessary from the conceptual design phase to consider the problems regarding the integration-interfacing processes, the informational links as well as the integration of the control functions into the product structure. In this way, the conventional functions made by the mechanical components are transferred to the electronic control and software components. This increases the constructive and functional performance of products and systems.

The activities promoting mechatronics are expanding more and more, due to a major interest in this field. Approaches in the field of mechatronics require advanced knowledge from multiple engineering fields (see Figure 4). They combine cinematic and dynamics, materials science, electronics and communications, the control theory, the information technology, micro technologies, and so on. Mechatronic systems are the result of an integrated design process and therefor are superior to any product achieved through a sequential (classic) design methodology[12, 16, 18, 27].

The integrated approach promoted by mechatronics is essential for the development and manufacturing of cyber-physical systems (CPS) [5] as well as for harnessing the Internet communication potential through internet of things (IoT) approaches [26].

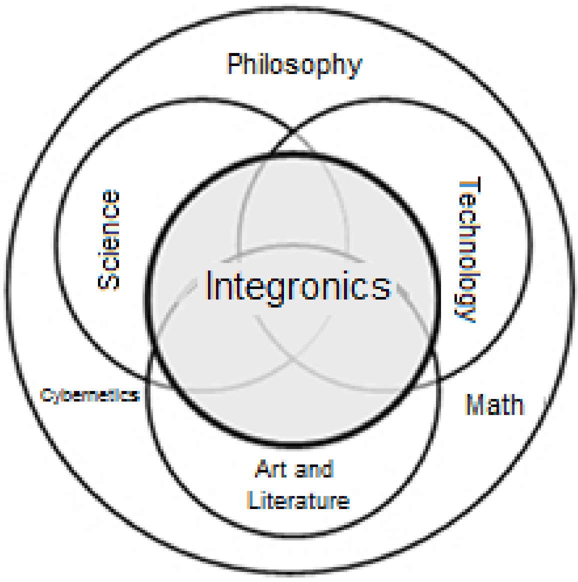

Figure 5: Concept of Integronics.

2.4 Mechatronic Revolution

Governmental decisions, projects and programs developed in the nineteenth decade (1980-1990) of the last century to promote the mechatronics philosophy in education, research and technological development ,generated a wave of renewal that had the character of a real revolution, the mechatronic one.This marked the shift from the information society to the knowledge society. So, two representative examples are presented:

In 1985, The USA Department of Commerce has elaborated a comparative report on mechatronics in the USA and Japan [8]. The report provided support for the decision of the National Science Foundation to finance the National Mechatronics Education Program. The project was coordinated by Stanford University.

A year later, 1986, at the EU-level, Advisory Committee on Research and Industrial Development (IRDAC) [12, 17], analyzing the problems of mechatronics in the EU, concluded that "mechatronics is a major need for European research and educational programs. This decision has stimulated initiatives at a national and regional level to develop projects and programs to promote mechatronics in education, research and technological development. Details of the projects and programs mentioned are presented in the paper [12].

3 The Integration-Complexification Process in the Nature and Technology

Integration is a natural process. The nature created forms and structures that promote development in this way. Based on superization principle, the whole, the system, has emergent properties due to the synergistic effect. In the knowledge-based society, efforts to promote the concept of integration in education, research and technology is a major need. Knowledge itself is the result of structuring and integrating information. ICT facilitates these efforts.

In the paper [9] F.Jacob (Nobel Prize in Genetics,1968) defined the concept of integron , as messenger of integration in human body. In the nature, the integration can be: genetic, through coercion, depending on your choice, random etc. Integrating subsystems can be: material-energetic dominant or functional-informational dominant. A.Restian, in the book [21] defined the concept of Integronics as The science of integrated processes and hyperintegrated systems, as the human body is.

It takes account of the indissoluble unity of the world in which we live and the need for unique perspectives on the world. The concept is illustrated in Figure 5.

Unity: science, literature and art, technology, takes place in the framework of mathematics, cybernetics and philosophy. Basis of integronics is not only the world unit but also the gnoseologic drive unit, of the subject knowledge of this world. Because there is no physical, chemical and even of scientific or artistic knowledge, human knowledge is unitary. The work of L.Lederman (Nobel Prize in Fhysics, 1988) related on the ARISE Project, 1995-2000 (American Renaissance in Science Education) was concerned with the approaches to train the teachers of physics, chemistry and biology in order to integrated teaching of the subjects. Studying the inextricable links between different objects and phenomena, integronics is trying to overcome the extremely narrow limits of sciences but cannot replace them. Sciences have been developed as a result of the limited possibilities of man to comprehend the realities of the world around us. Need for progress removed the borders between sciences and the evolution towards interdisciplinarity and after all to transdisciplinarity. In this manner have appeared chemistry-physics, biophysics, biochemistry etc.

Accentuating the limits of fragmented approaches and the need for a global vision, integronics try to avoid such situations, emphasizing more strongly that we need to consider not only the subsystem on which to act, but also his links with other subsystems and finally the suprasystem of which it's a part. Integronics inscribe herself in the context of modern thinking which after all is a global, probabilistic, modeling, operational, transdisciplinary and prospective one.

Integronics conception is one of the great gains of mankind due to the mechatronic revolution. It's very basic principle: the principle of order and systemic organization which is contrary to the second principle of thermodynamics, could be made due to consideration of information. In the formulation of the second principle of thermodynamics information is not considered.

Extremely useful, this process of emergence of interdisciplinary sciences has not been enough to solve complex problems of this unitary world. It is natural, because, being more than the sum of its parts, the unity of the body for example cannot be restored by simply unifying neuroscience with the endocrinology or of psychology with immunology and the world alone cannot be retrieved by a simple unification of astronomy with physics, with chemistry and biology.

Because information is the key element in mechatronics, the impact of technology goes beyond areas of economics, being essential in the social, cultural environments etc.

This explains the great interest in the world to launch initiatives and develop special programs for this area. These approaches reinforce the belief that in the knowledge-based society, cultural relevance depends on technical and technological performances[12, 25].

4 Mechatronics and the Learning Organization

The notion of learning organization was launched by Prof.P.Senge from MIT in 1990. In 1991 at MIT was founded The Center for organizational learning. The center developed, and in 1997 became Society of the Learning Organization [23, 24].

Senge defines the Learning Organization as an organization where people continually expand their capacity to create results they truly desire, where new and expansive patterns of thinking are nurtured, where collective aspiration is set free, and where people are continually learning how to learn together.

It is easy to understand that, as the world becomes more interconnected and business becomes more complex and dynamic, work must become more learningful.It is no longer sufficient to have one person learning for organization. The organizations that will truly excel in the future will be the organizations that discover how to tap people's commitment and capacity to learn at all levels in an organization [Senge, 2006], [23, 24]. Traditionally, productive organizations have been viewed as center of work.

However, The Learning Organization sees the productive organization as not only a center of work, but also a center of learning.

As business organization, schools are learning organization too. Dimensions of the learning organization are:

Individual level: The learning organization is a place of continuous learning and learning becomes a conditioned reflex, a habit.

Group level: Teams are encouraged to reflect on how they work, not only so that accomplishments can be celebrated but so that needed improvements can be introduced.

Organizational level: At the level of the organization, learning organizations connect learning to organizational transformation; learning is about developing the organization itself.

In the context of challenges for smart cities building, a new dimension is added to the learning process, that is: *Communities level.* The smart city is a *Communities of the learning organizations. The Smart Country is the country of the learning communities* [25, 28].

P.Senge defines the discipline of the learning organization: Personal Mastery, Mental Model, Shared Vision, Team Learning and System Thinking.

The discipline consists on a body of theory and technique that must be studied and mastered to be put into practice. A discipline is a developmental path for acquiring certain skills or competencies.

Personal Mastery Organizations can't learn unless their members begin to Learn and develop their personal abilities to achieve desired results.

Personal abilities and competences mean to be active able to, to have a creative attitude toward life, to live actively and not to be passive.

It is the discipline of continually clarifying and deepening our personal vision, of focusing our energies, of developing patience, and seeing reality objectively. [23, 24, 25].

Mental Model Mental models determine how a person thinks and acts. Even though people always don't act according to their mental models, their behaviors are based on a mental image [23, 24].

In the learning organization, mental models are the discipline of consideration, discussion, dialogue and study. With this discipline people try to reach some agreement about suitable and realistic mental models.

The deeply ingrained assumptions, generalizations, and even pictures or images that influence how we understand the world.

Shared Vision Consists of the capacity to create a shared image and view of a future which we pursue it. A collective experience which is the total of each participant's personal vision.

Senge believes that action and reaction with people shape a shared vision which created only via the awareness of organization goals and compatibility between individual visions and developing these visions, towards general purpose.

Team Learning As Senge says, the world is full talented people, but it is important that they should know how to work and act together. Conversation and practice are the two important components in team learning.

Team learning is seen to be crucial because team, not individuals, are the fundamental teaching unit in modern organization[23, 24, 25].

System Thinking Systems thinking is a way holistic. It is a framework that emphasize on understanding of internal relations of phenomena, not on identifying them one by one.

Senge sees systems thinking at the heart of his "learning organization" models, where all of organization members develop an understanding of the whole rather than just fractional parts of organization in terms of structures, processes, thinking and behavior.

Analyzing the requirements of the five discipline of the learning organization it is easy to understand that mechatronics is true environment for smart education and organizational learning. The mechatronic platforms are the basic infrastructure for such environments. The specific approaches are appropriate for all the levels of education, since kindergarden to adult education [12, 25, 28].

5 Romanian National Platform for Smart Education and Organizational Learning

Mechatronic philosophy developed in Romania since 1991 by developing the branch of mechatronics in engineering in the main technological universities from Brasov, Bucharest, Cluj-Napoca, Craiova, Galati, Iasi and Timisoara [12, 28].

In October 1999, were launched the postgraduate courses on Technological education for the teachers from gymnasium and secondary schools. The educational program included mechatronic subjects. On the other hand, the Departments of mechatronics from universities, in cooperation with Festo Romania developed training courses for specialists from industry.

Festo Romania is the representative of Festo Germany, which is the main logistic support for the International Olympiad of Mechatronics.

As a result of cooperation at the academic level in education and research activities too, along of a quarter of century (1991-2016) the National Mechatronic Platform was developed [12, 25].

It is conceived as a "*national mechanism which aims to activate material and human resources on a local, regional and national level, and also to ensure the systemic approach, in a holistic way of dealing*

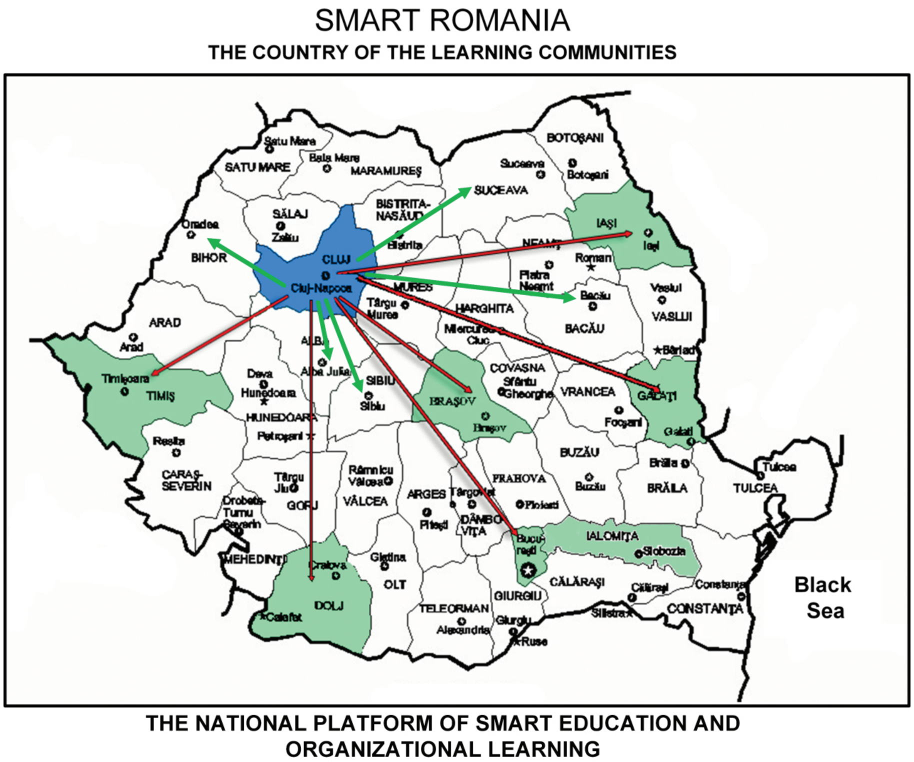

Figure 6: The National Platform for Smart Education and Organizational Learning.

with complex problems regarding education and training in the knowledge society".

At that stage (the pilot stage) the platform integrates seven Regional Centers of Mecatronics developed on the structure of the Mechatronic Departments of the technological universities from Brasov, Bucharest, Cluj-Napoca, Craiova, Galati, Iasi and Timisoara.

The regional Center founded in Technical university of Cluj-Napoca is the coordinating one. Within the regional Centers will be further developed Virtual Mechatronic Competence Centers.

These will include: virtual laboratories, and libraries, databases, sources of knowledge and other facilities regarding access to knowledge in the field of mechatronic for students, researchers, professors or any other interested users.

After the pilot phase is validated the Platform will be able to extend integrating other universities, organizations, institute or companies. In this way the Platform will become a veritable national company producing knowledge in the field of mechatronics, and the universities will become real Knowledge Factories. For practice and experiments at all the levels in education and training activities the mobile lab of mechatronics and portable one were developed.

The portable lab for mechatronic education makes possible experiments every were and every time being very efficient to stimulate initiative and creativity.

In the last years, 11 universities in the country developed mechatronic departments. Also, The National Institute for Research and Development on Mechatronics and Measurement Technique is integrated in the structure of the National Mechatronic Platform[12, 25, 28].

The partnership of our university with CIRET and Prof.Basarab Nicolescu was very fruitful and helped us to discover the innovative potential of mechatronics for education and research activities too.

Prof.Basarab Nicolescu is Honorary Citizen of Cluj-Napoca since 2007, and Doctor Honoris Causa of our university since April 2008.

Now, The National Mechatronic Platform is the scientific foundation of The National Platform for Smart Education and Organizational Learning. Based on this scientific support was launched the Project: Smart Romania: The Country of The Learning Communities (Figure 6)[12, 28].

6 Conclusions

Mechatronics, the XXIst century technology, the integrative philosophy and science of intelligent machine, is the foundation for the development of smart, competence-based educational technologies in line with the knowledge-based society. Mechatronics platforms are the basic infrastructures for intelligent education and organizational learning.

Mechatronics education aims at developing systemic thinking, integrating and shaping skills to work in a team, skills indispensable to the worker in the knowledge production.

The flexibility in action and thinking, the result of mechatronic education, are essential to stimulate initiative and creativity. Flexibility and reconfigurability define the features of the mechatronic technical systems resulting from the integration of their information links into their structure.

In other words, the mechatronic technology, through the integrated approach of the components: material- energy-information makes it possible to materialize the concept of quantum realism.

This context draws attention, both in education and research, on the issues of quantitative and qualitative evaluation of information integrated into the structure of intelligent products and systems. The scientific foundation based on mechatronics and organizational learning concept are major needs for transdisciplinarity learning. Being transdisciplinary asks for transdisciplinarity learning.

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