LEARNINNG ABOUT THE COMPLEXITY OF NATURE BY INITIATING YOUNG STUDENTS IN SCIENTIFIC RESEARCH

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Abstract. This paper presents the results of the Nexus program that has been set up 8 years ago in order to structure and develop a suitable environment for work and creativity in a Romanian high school. The key target of the project is to awaken and expand the specific skills and abilities required in creation, innovation and research, particularly among the teenagers. More specifically, it has been meant to encourage the inherent curiosity spirit, to enhance the analytical attitude and to actively promote independent thinking of the young generation, as well as redefining the concept of „work" in interdisciplinary teams. An additional purpose consists in publicizing and debating the scientific results in dedicated summer schools (*Fractal* 'xx and *Atlanykron* - a little island on the Danube river near the ancient city Capidava). This presentation also includes the description of the CONNECTUS concept: *a **Personal Laboratory** (PL) for a Personal Computer (PC) connected to Internet.* This latter element provides an extremely fertile framework for home-based research activities specifically targeted for the young generation in order to assist and encourage them to expand the personal knowledge and to develop the abilities of understanding and respecting the Nature.

Keywords: complexity, continues learning, personal laboratory, learning by discovery.

1. BACKGROUND

The latest developments in computing and information technology (C&IT) enabled new and performing methodologies based on nonlinear models and theories. Moreover, nonlinear approaches facilitate the restructuring and expansion of research networks at international level, thus allowing a better approach and a deeper understanding of natural phenomena, particularly those related to Life, Environment and Human Factors.

Furthermore, the knowledge and data accumulated in different research fields as a result of international and/or interdisciplinary cooperation can be used to set up a conceptually novel framework within which one can act and approach problems with improved efficiency and according to Nature-compatible principles. This new approach is known as "The Science of Complexity" and has been developed and promoted by prestigious academic and scientific personalities, such as Ilya Prigogine, Benoid Mandelbrot, Rene Thom, Per Bak, David Chalmers, who worked either independently or in interdisciplinary institutions, e.g. the renowned Center in Santa Fe, New Mexico, USA.

The conceptual developments within the "Science of Complexity"-originated frame-work joined and combined with those resulting from the C&IT methodology have generated the basic ingredients for forging a new society, the so-called "Knowledge-based society", which entails fundamental changes in the present socio-economic development and educational system.

In this context, it is most significant to highlight the European Community (EU) objectives set in March 2002, in Lisbon, at the reunion of the chiefs of European states and governments. This objective stipulated that, by 2010, the European economy should become one of *"knowledge, the most competitive and dynamic in the world, capable of a durable increase, along with a quantitative and qualitative improvement of the workforce*

occupancy and a more profound social cohesion”.

How could one practically reach such a goal? The socio-political-economical re-shaping of our human environment into a "Knowledge-based society" clearly is a strategic and crucial requirement for our future. In this context, our practical application of the above-mentioned Science of Complexity originated framework becomes therefore a strategic tool which could greatly aid in achieving and implementing the above mentioned European objective. Implicitly, aiming towards such an objective and carrying out the necessary changes are even more important for Romania, given its present socio-economical situation and its transition oriented towards actual European integration.

In fact, if we were to use Karl Popper's definitions, economy is a transmutation of a part of the so-called **Third World** (*which includes all the products/results of the Mind and Spirit: the language, notions, theories, ideologies, religions, etc*.) in The **First World** (*the physical one*). As Karl Popper himself emphasized: "...if you consider the Third World from a Darwinist point of view, that is considering language as a tool and the theories presented either orally or in written as tools as well, then we realize that theories are tools similar to our eyes or ears, tools which we use in the First World, i.e. in the physical one. This clearly highlights the tremendous importance which “the Third World” has to the man's life”.

This suggests once more the important role played by **the educational process** in the sustainable development of mankind. Thus, the quality of life depends undeniably on the quality of concepts, of models and customs and on the personal vision of the world and the environment. At a core factual level, mankind's subsistence and progress themselves are essentially determined by the economy. Simultaneous with this development, mankind has been generating through this process an increasingly harmful and even deadly impact upon the very substrate unto which it created the economy, and on which it is vitally dependent: the environment. Therefore, finding and applying a responsible and suitable approach when dealing with this delicate interdependence is a topic of outstanding importance.

Identifying solutions for a lasting and sustainable development in harmony with nature is difficult, due to the heavy heritage of the industrial society based exclusively on competition and profit and inherently entailing pollution, waste and a moral scale of values centered on material profit rather than he above mentioned conceptual values. The search for solutions to the world’s present impasse is obstructed also by the global socio-economic fragmentation induced by the facilities offered by the informational society, such as *e*-dividing and the *e*-exclusion generated by phenomena such as work delocalization, virtual instrumentation and virtual shopping.

Few people clearly see and realize that an enormous gap has been created, and is relentlessly widening, between the quasi-exponentially increasingly spreading and availability of infrastructural components (e.g. IT hardware and software) on one hand, and the degree of their understanding, assimilation and -therefore- their ultimately efficient and wise usage, on the other hand. This recent problem of our contemporary society is rapidly proliferating, not only in its purely 'technical' aspect related to the lack of access to such technologies by certain categories of people or nations (the so-called "digital division", and quite mediates). Besides this technical facet, the problem also encompasses other extremely important issues, like the usage of such IT resources and the application of the obtained results as well as the sharing of the resulting benefits, while at the same time other influential and thorny aspects are related to the interfaces and relationships among individuals, society and economy, relationships both within each category and between any of these large categories.

Consequently, for one society to survive and develop even further into becoming a competitive force capable of success under such new harsh and constantly changing circumstances, we strongly believe that it is imperatively necessary to generalize and actively apply the following measures, on a scale and at a magnitude as large as possible:

- **Generate a new interactive Mass Media Environment**: This should allow the achievement of two fundamental and vital goals. First, it should be capable to diffuse the products of the "Third World" on a large scale by reaching a wide audience. Secondly, it should be highly interactive to enable its constant re-shaping into new forms, elements and formats, according to the feedback, interests and talents of the participants themselves. Technically, such a solution can be improved by adapting it according to the well-known Internet model, and also additionally completing and complementing the Internet-based part by integrating it together with Radio, TV and WAP;
- **A thorough restructuring of the Educational System** so that its 'classic' fundaments would be not only changed and improved but also expanded and re-formatted by including new elements, such as Continuous Teaching/Learning, non-formal and Informal Teaching/ Learning, On-line/Remote Teaching/ Learning and Self-Learning. This restructured Educational System would then encompass, include and use the modern facilities that are presently available and at the same time prepare alumni who can easily grasp and adapt to the Shock of the Novelty and therefore function at their full human potential in (any) modern society. Moreover, besides these structural changes, the highest priority and attention will also be given to the seeding and development of the "soft" skills, such as:
  - **Improving communications** at inter-human and human-to-Technology levels, according to the new developments and the last novelties in the field of telecommunications and IT; and, at last but not in the least,
  - **Changing the mentality** at individual and society levels, both in governmental and private spheres, in order to establish an effective and lucrative Public-to-Private Initiative Partnership. The main target of this Partnership would be the development of the Human Being as well as improving the standard of life.

Engaging in the struggle of achieving and implementing all these aims is vital as they can actively contribute not only to the evolution of the Mankind in general, but -even more importantly- would specifically enable the survival of the National Entity in a world that is in an accelerated globalization. This would preserve national specific features, with direct consequences on creativity and inter-economical and/or inter-cultural creation of new outcomes, thus contributing directly towards the betterment of the quality of life and ensuring a stable socio-economical growth.

In this context, one can say without any doubt that positively restructuring the Romanian society is a complex process, a real challenge. It involves both modernization of the infrastructure and the technologies to the competitiveness and quality level required by a real participation in a global market, and major changes in the mentality of the social segments taking part in this process. As one can infer from all the above presented arguments, the difficulty is also increased by the fact that this restructuring process is taking place in the context of an unprecedented socio-economic metamorphosis, both in Europe and in the whole world. In this extremely dynamic context, governed by mostly divergent interests, the states of the world are compelled to find viable and immediately applicable solutions. This process of continuous harmonization of interests stipulates the conditions of the European Union consolidation, as well as the integration of Romania in this Union.

2. CCS PROGRAMS

In order to motivate the interest of the society and especially that of the youth in education, specifically in science & technology, is a difficult problem. The process of "lock-in" (which will also be referred to later) characteristic to a market economy has stabilized several careers that are nowadays considered financially attractive: *show business and entertainment, advertising, sports, management, law school*, all of them being characterized (or considered) as fast & certain carriers towards quick achievement of

fame and fortune, generally based on native qualities of the person involved.

The continuous long lasting effort, as well as the necessity to operate in an abstract framework on the basis of a formal language, leads to a dramatic decrease of the interest in scientific or engineering-related careers. This situation is even absurdly paradoxical given the more and more highly technologically - oriented outline of nowadays world. Some of the causes responsible of this situation are:

- The lack of recognition of the social importance of engineers and researchers & scientists in general,
- The absence of efficient popularization of the satisfactions and results offered by such careers;
- The contrast between the rewards imparted by Society, on one hand, to an innovator, or a scientist with two university degrees or a Ph.D. or other merits, and, on the other hand, to a soccer player, a movie star, a TV presenter, or even a simple participant to quasi-intellectual contests like “The Wheel of Fortune” or “How to Become Millionaire”, not to mention of those without even such pretensions, like “Survivor”.

As a consequence, the difficulty to identify, educate and propel youngsters with the necessary skills and knowledge for a subsequent integration in our research activity in Complexity Science has intrigued us and consequently motivated us to conceive and start in 2001 a program dedicated to the identification and formation of youngsters with native skills for scientific research. Furthermore, we have even carried out an opinion poll in order to determine the relevance of this situation in Romania and to subsequently conceive a properly designed program. Such a program was obviously dictated by the need to amend the present situation in Romania not only by addressing the educational and formative aspects, but also in trying to shift the society wide attitudes and mental prototypes that had been ingrained in the popular consciousness.

The program was desired to equally target teachers and students, parents and employees, in short, any person of age between 12 and 65 years old willing to listen, to share his views and especially to improve himself/herself. Among the conclusions of the surveys we mention:

- The lack of a unitary vision for the educational process. This vision has to be forged taking into account a variety of complex contributing factors: the needs of the present young generation, the trends/areas for the future evolution and development of the Society as well as of science & technology, the synchronization and symbiosis with the ’other half’ of the forming environment (family, school, friends, general societal context), the dynamic induced by C&IT in the modern educational process;
- Malfunctions in the organization, coordination and harmonization of the educational process at all its levels: primary & secondary schools, high schools and colleges, and even Universities. These malfunctions induce major discontinuities in alumni's life when passing from an educational level to the next and help propagating a general discomfort (in the best case) or even mistrust in the educational capacity of that specific environment. Moreover, such errors and miss structuring have a very deleterious and poisonous long-term effect by generating mutations in the occupational levels of various professions, depleting the talent pool of a nation, encouraging the immigration process and thus crippling one’s economy capability of being competitive in the high-tech areas, i.e. those specific areas which really contribute to the progress and prosperity of a nation/society.
- The lack of interest of the academic staff itself (as well as of the governmental factors) in reforming the educational structure (i.e. the desire to preserve the statusquo which is viewed as already ’good’ or at least familiar with in terms of management and human relations). An antidote to this predicament is to shift the general mentality (more details are given below) and to highlight the importance of, and offer the possibility of personal active

involvement in motivating the youth for a scientific carrier and in cultivating their scientific and/or technological skills.

- The present emphasis of the in-use educational programs on the mechanical transfer, accumulation and reproduction of information, without any (or very little) accent on stimulating curiosity, innovatively, (self-) exploration, finding and enhancing the youngsters' native skills (scientific, technical, or of any other nature), not to mention the poor connection to the applicability and impact of this education for subsequent jobs or professions.
- The lack of expertise and experience of the teachers in two main directions:
  - integrating the information of their discipline in an interdisciplinary context, and
  - structuring and leading scientific projects oriented toward solving real problems, with practical relevance for those who study the topic.
- The lack of a properly equipped experimental infrastructure. This includes not only modern audio-visual tools (powerful PC, projector, multi-media capabilities, etc.), but also a systematic and extensive array of measurement devices, workstations, data analysis software, etc., that should make up the laboratories in which students should examine practical aspects of the studied discipline. This critical infrastructural deficiency leads to an unavoidable subsequent limitation of the projects at just theoretical levels, less appreciated by the students and also with much less impact for their preparation as future specialists.
- The lack of an entrepreneurial mentality. This aspect, much less visible and significantly less perceived by many factors of decision, is also multifaceted, encompassing various aspects:
  - Cultivating and developing a different mentality and a different attitude, in which not only "Knowing" is enhanced. "Doing" should also be included, but even here a subtle differentiation must be perceived. "Doing" should refer not only to the (previously mentioned) aspect of facilitating students to perform practical experiments and confront them with real-life problems in order to enhance their practical solving skills. An equally important facet of "Doing" should be oriented in enabling them to follow their visions and dreams, to find the proper channels to further develop and put into practice their ideas at a macro-economical level. This aspect is automatically linked with the next aspect:
  - Provide managerial, administrative and financial know-how of real importance, relevant for real situations, to the technical students or any other technical inventor. Reversely, in the wake of a huge number of students enrolled in the last period in "management" courses or faculties, it became quite clear the acute lack of technical knowledge and of understanding of the basic elements of the activities that are supposed to be managed (with painful, sometimes catastrophic and sometimes even hilariously absurd outcomes). Therefore, it is clear that management & financial know-how has to be combined with technical and scientific knowledge.
  - The set-up and long term commitment in maintaining proper channels of funding, administrative assistance, etc. aimed to support those innovators who want to create their own start-up company or small business 'cell', which can contribute positively to the entire society & economy. This would encourage those who have fresh and economically viable ideas to apply practically their innovative approach in any field. In this way we could strive towards eliminating the current situation and mentality characterized by a very reduced number of such projects and by a lack of enthusiastic determination due to the generally perceived opinion (especially at high decision levels) of "cannot be done" (or even worse, "why should it be done?").

- The lack of clubs or other specific venues dedicated to people sharing common interests and hobbies and which can constitute the seeds of a coherent activity at an institutional level.
- The lack of specialized shops dedicated to selling electronic and/or other technical components, do-it-yourself (DIY) kits and other similar assemblies or such materials necessary for building experimental projects, in the same spirit as the mega shops dedicated to gardening, house improvement and furniture.
- The lack of viable mechanisms for financing as well as for marketing, advertising and economical exploitation of the results obtained by 'hobby' meetings (inventions meetings and exhibitions, national contests promoted and sponsored by renowned personalities and/or interested institutions or governmental agencies).
- The narrow mentality of the private sector which assumes as "healthy" or "normal" a passive attitude, an intrinsic non-involvement in the financial support of the educational process. This is also enhanced by the presently preconceived ideas such as*: "The Romanian school can no longer provide valuable people hence it is better to bring in specialists from abroad"* or *"the specialists have already emigrated to developed countries, hence the Romanian education has no future without the leaders"* or *"today's youngsters do not have the necessary potential to become tomorrow's leaders, thus the effort is useless and a bad investment"*.
- An aggressive mass-media which popularizes sensational news, events meant only to shock or to excite (disasters, crimes, wars, show business, sports) and which includes rather randomly and occasionally news on scientific personalities, Nobel prize winners, authentic discoverers or inventors. Programs such as "Big Brother" or "Survivor" are widely marketed and promoted due to their role as profit engines and thus proliferate, generating in today's youth a vision of the world contrary to the one necessary for the formation of future intellectual and scientific leaders. Neither the private sector nor the government are interested in financing complementary or alternative programs focused on different topics (why not have instead a "Smart Brother"?). Consequently, a vicious circle sets in and the system is in an apparent lock-in phase without any alternative beneficial for both the youth (who could find and exploit their talents and dreams) and the society/economy (which could benefit, albeit in a very long-term and indirect manner, from the formation of specialists in various key areas), each aspect feeding upon and strengthening the other.
- The TV channels specialized in science, such as "Discovery" present exceptional events, but their typically high level and style of the programs are less oriented towards education and are not aimed at an interactive training of future intellectuals. This ultimately generates a paradoxical consequence: blocking the interest for a scientific or technical career, as the presented scientific fields and themes now acquire a mythical nature, extremely difficult and intangible for the youngsters and amateurs. This creates the impression that science, technology, creativity, inventivity and their application by personal implication in these areas are far-fetched in the present context. Therefore, the contribution of the programs broadcasted on such channels is a double-edged sword: on one hand may highlight the essential role played by science and technology. On the other hand, however, because the information presented here is not specifically dedicated or 'packaged' at a level suitable for the young audience and in a form that would encourage their interaction, one gradually ends up considering these are activities in which one cannot participate. This has dangerous negative effect by transforming the youngsters into passive spectator of others' amazing realizations in distant countries. However, this progress provided by such

breakthroughs or realizations does not benefit directly neither the viewer nor the region in which (s)he lives, and at the best may strengthen the idea that 'it cannot be done here", thus indirectly and subtly favoring later immigration ("*one must go to USA to do microelectronics*"). This strengthens the previously mentioned mentality that "we can do nothing here" and therefore leads the youngsters towards the sensational "Big Brother"-type of shows which become perceived as much closer, much easier to understand and participate, and which are also viewed as potentially much more rewarding financially.

Besides the general perspective summarized above, there are some other quantitative aspects regarding education for realizing a knowledge-based society, and which also resulted from interviews, polls and discussions initiated by CCS:

a) Only 5.4% (!) of the questioned youngsters (aged between 12-16 years old) intend to follow a scientific carrier;

b) Only 1.5% (!!!) of the questioned youngsters have skills that could allow them to follow a scientific carrier;

c) 63% of the persons with ages between 45-65 that were questioned in the poll have always been interested and fascinated by science and science-related fields (science-fiction literature, scientific popularization journals, and technical-hobbies clubs);

d) Just 18% of the youngsters frequently watch scientific programs (e.g. the "Discovery" channel) or surf on the Internet in search of web pages dedicated to scientific domains;

e) A whooping 82% of the questioned youngsters do **not** have basic scientific knowledge, and are **not** familiar with the concepts which could allow them to understand the information taught in high school and upper level educational institutions;

f) Amazingly (or maybe not…), 93% of the questioned youngsters have used the personal computer just for games, *e*-mail, Internet, music and movies (it almost seems redundant to have a microprocessor in the PC…);

g) A crushing 98% of the questioned youngsters do not know if and how a PC can be used for physical measurements or as a part of a physics or science experiment;

h) Finally and painfully, 84% of the *high school* ***teachers*** do not have the capability of correlating information outside their lecture subject, do not approach new topics in an interdisciplinary view and have not conducted any practical or lab activities (for various reasons: lack of proper materials, no lab guiding, no experience).

From the synthesis of these entire data one can easily understand the difficulty of generating a coherent national program dedicated to fostering the interest of today's youth for science. In this context, CCS has elaborated (in the year 2000) a training program intended to raise the awareness on this issue and to actively and positively contribute in rectifying this situation, for all the parties involved: youngsters, parents and teachers. The program included setting up and carrying out the following actions:

1. a package of activities dedicated to draw the attention of the public and to widely highlight the strategic importance of science, research and technology in the evolution of the modern society and for the future society and economy (discussions, radio and TV shows, summer schools, edutainment programs).
2. a prototype program implemented in the "Tudor Vladimirescu" theoretical high school in 2000 : (www.csc.matco.ro/ nexustineret0.html) and developed in the Terra Nexus network after 2006: (www.nexustsv.ro), activities dedicated to identifying gifted youngsters with skills for a scientific carrier and including them in a systematic research project program carried out in the period 2001-2008 by CCS and partners: International Center of Biodynamics, Scientific Association CYGNUS, Polytechnic University of Bucharest.
3. Generating the minimum infrastructure necessary for experimental research study executed either individually (e.g. at home), or in an organized framework (e.g. at school), using products realized in a

partnership with the Romanian company "ASTECH Solutions Ltd." (The CONNECTUS hardware/software package for PC-based edutainment related to specific scientific topics, which will be presented in great detail in the last section of this paper).

In this paper, we present the structure of the Nexus-T program as well as the CONNECTUS system. Our main purpose is to transfer our experience gained during the last 8 years to a wider audience. Such data we hope would be most useful for those interested in setting-up and developing community frameworks of best practices in the WWW environment dedicated to "Teaching and Learning Science" and initiated by the "Hands on Science" EU program.

3. THE NEXUS-T PROGRAM

The general objectives of the NEXUS project are:

- Redefining the teacher-student relationship within a continuous teaching process, specific to the knowledge-based society;
- Motivating the educational act by:
  - Stimulating the curiosity and interest for science and technology;
  - Employing actors to enact various scenes for promoting universal, cultural and scientific values in the sense of the 'Third culture' (as defined by Snow);
  - Involving school children and students in effectively solving real problems of community interest through scientific projects (such as NEXUS) that can offer the background for forming new abilities (ingenuity, pro-active attitude, the ability to communicate and work in a team, adaptability, etc);
  - Regaining the school's prestige, improving the teachers' and researchers' image, as well as emphasizing in multiple ways the role that science and technology have in developing humanity, beyond the Complexity Wall.

The NEXUS project starts from the premise that **a well-asked question can initiate a specific cognitive process**, able to arouse interest and curiosity and to motivate the effort of accumulating knowledge. For this reason, the program was conceived to stimulate young people's ability to generate pertinent questions in the field of Complexity Science and also to find their answers through a process largely based on self-instruction, experimental research and communication with other students and researchers/instructors interested in the same topic.

The novel and innovatively creative contributions brought by the NEXUS program are configured in a multi-component ensemble formed of:

- **The NEXUS room**: a space dedicated and equipped especially for documentation, courses, multidisciplinary dialogue and consulting, lab experiments, etc. The activity in the room is carried out in groups structured around various subjects chosen from the Open Projects database;

Foto 1

The „Nexus environment" – a complex place dedicated to reveal the beauty of science

Foto 2

- **The complex teaching object** (CTO) is a hardware/software synthesis that allows experimental multidisciplinary exploration of the processes and phenomena of

interest, according to the topics selected from an Open Project. The CTO was designed in such a way that it specifically enables and stimulates creativity and formation of new abilities: *attention, ability to correlate the knowledge gained during the course, initiative, collaboration, and communication within interdisciplinary teams, etc*;

- **Teacher "Up-grade":** This is a program of preparing the teachers for the problems involved by the previously and individually assumed Open Project. It consists mainly of intensive courses (including *e*-learning) for assimilating concepts and notions necessary for the use of the infrastructure and the software that accompanies a CTO, for completing the curriculum with novelties (especially from the Complexity science), and for correlating the various primary knowledge elements through an integrating and multidisciplinary approach.

The NEXUS room, specially designed and equipped for the message which the NEXUS program wants to deliver, enables:

- **Scientific documentation** through the Internet network and through the NEXUS library for the major specialty topic of the school: biology, physics, informatics, etc. The NEXUS library holds magazines, books and electronic books. It becomes richer through donations, book purchases and especially through the enlargement of an Internet-acquired database. This database is filtered according to the school's specialty topic and is translated and multiplied locally (For this purpose a group of young participants enrolled in advanced English courses; the teaching activity acquires thus an objective of immediate general usefulness);
- **Experimental research** takes place in two specially designed areas, each comprising a CONNECTUS system adapted to the topics chosen in the structuring stage of the NEXUS program. These areas are also integrated in an Intranet network formed by 4 computers that ensure data processing, modeling of the studied phenomena, preparing materials for communication sessions, publishing, etc. All these activities are carried out through a well defined scientific project;
- **Meetings and discussions** within the formed study groups, work meetings for elaborating projects concerning the high school, projects that would be submitted for financing (Ministry of Education, educational departments, City halls, sponsors, etc.);
- **Meeting personalities** activating and well known in a field identical or similar to the school's specialty topic;
- **Conducting micro-courses** for those who approached (or want to get involved in) a specific research topic, using also the video conferences to involve professors form different countries.

Even from its first year the NEXUS program attracted 65 high school students from the 10^{th} and 11^{th} grades (16-17 years old) and enabled the structuring of three study topics, one of which became a topic assumed by a group of participants in partnership with University students, teachers within that respective high school and outsiders. Each year, more that ten of these high school students, the most active and meritorious ones, were selected to attend the COMPLEXITY Summer School held in ATLANYKRON (a little island on the Danube river, near Cernavoda – www.atlantykron.org). On this occasion, the first stage of the project was finalized by participating to a posters session, defining the subjects to be approached in the next year and identifying and assigning/assuming the roles within the group for those future activities.

The Program NEXUS was conceived as a platform for non-formal education oriented toward an interdisciplinary approach of a scientific subject, a personalized program that would construct a solid knowledge and applicative basis. This effort was specifically tailored for the preparation and the interest level of the youngsters, while at the same time also considering the availability of the academic staff and the particularities and tradition of the respective high school. The

practical implementation of the program consisted of carrying out the following steps:

- A complex evaluation of the abilities and performances of the alumni from 10th and 11th grade (16-17 years old) through an original multiparametric method. This involved determining the various elements (sensitivity and specificity of a group of youngsters, the optimum communication type, personal inclinations and inherent abilities, etc.) that would allow a correct personal choice of topics of real interest and actual importance for each involved participant and her/his formation;
- The evaluation of the preferences, potentiality and availability of the high school's academic staff for integration in a non-formal education program with the perspective of subsequent financial self-sustainable by means of sponsors, and participation in national and international development programs.
- The development of the package NEXUS dedicated and adapted to the characteristics of the high school and which includes: The preparation of study projects dedicated to a period of two semesters (including subjects selected through previous opinion polls) and of a package of activities intended to raise the awareness on the importance of science & technology in the evolution of a modern society (discussions, radio and TV programs, summer schools, edutainment programs, brainstorming); The realization of supplementary educational objects and tools (hardware/software infrastructure) specific for the experimental development of the proposed themes;
- Structuring a NEXUS library which should contain the primary information necessary to the development of the program;
- The selection of high school student groups which would actively participate in the program, followed by choosing the main topic of each individual project;
- Scheduling the activity calendar;
- The preparation of a specific training targeted only for the teachers involved in the project;
- The preparation of the NEXUS room: connecting the high school to the NEXUS network of CCS, followed by the surveillance and assistance of the activities carried out in the framework of the program;
- Selecting the participants for the summer school ATLANTYKRON-xx, organized by CCS in partnership with different nongovernmental associations.
- The final evaluation of the program.

Related to this latter aspect, the following important **conclusions** could be drawn:

- Actively involving teenagers in scientific and technically oriented programs DOES motivate them and greatly stimulates their interest for school/learning in general and for science & technology in particular. Therefore, this active implication in such a highly interactive and 'hands-on' type of program is a decisive factor in the personal development & fulfillment of the teenagers, thus essentially contributing to their formation as future responsible members in a Knowledge-based Society;
- The major difficulties we encountered are related to more main aspects that are interdependent, as follows: -The necessity (and the large effort required to) to build from scratch modern educational and infrastructural set-ups. This does not refer only to PCs and projectors, but especially at endowing labs (with necessary machinery, equipments, consumables, etc.) for experiments, and even supplying material (books, CDs, etc.) for building the necessary data-bases or libraries which play a vital role in coaching the new generation and encouraging it in self-study;
- The capability to sustain such programs and their auxiliary activities in a long term effort, which requires considerable commitment (including sustained and uninterrupted financial support) and vision at high decisionary levels;

It is clear that such a program developed and applied for only one high school can serve as 'template benchmark' for similar programs

that can be applied elsewhere. Moreover, it is obvious that the relevance and ultimate utility for the society & economy can be increased with orders of magnitude if such a program does not remain a solitary element but is embedded in a larger network aiming at developing and interconnecting such programs at ALL the other levels: primary schools, Universities, companies and institutions interested in promoting education and know-advancement in science and technology. Without such a general concerted effort, there is no continuity and the skills and talents cultivated in this program would remain fruitless if not further enhanced in the subsequent educational stages and applied practically.

We believe that all the above issues have to be addressed by the joined action of governmental agencies, private companies and sponsors, but also by the continuous effort and preoccupation of the school staff and students themselves, including the parents. This can be aided by promoting awareness increasing on TV, radio, Internet, etc., in order to publicize the usefulness and good results of such programs, and therefore to help shift the current general 'anti-scientific' mentality.

4. CONNECTUS: A NEW PHASE IN THE INVOLVEMENT OF THE YOUNG GENERATION IN "DELOCALIZED" SCIENTIFIC RESEARCH

CONNECTUS is an assembly of both hardware and software products and services targeted at developing the personal experience and involvement with various scientific and technical topics. The whole CONNECTUS ensemble has been formulated and fabricated according to top international requirements, especially bearing in mind the necessity of helping to educate people for an informational & Knowledge-based society. CONNECTUS represents an intelligent mode of probing and learning by enabling a different novel way of finding, gathering and understanding information about natural phenomena in the world surrounding us. It can be considered as a new interface to the underlying scientific principles that animate our world, an interface that allows the user to perceive Nature and to grasp the utility and the role of the PC in a new manner and using a different approach: a combination of playing, teaching, learning and self-discovery. CONNECTUS is an invitation to interactivity, communication, and collaboration within teams structured '*ad-hoc*' that would approach problems of maximal difficulty. The teams can be 'delocalized', i.e. not necessarily placed together physically under the same roof, because PC-based Internet connections can allow communication and information transfer. As such, the CONNECTUS kit and the PC on which it is installed can be placed anywhere: in the school, at home, in the summer camp, etc. Moreover, this interconnectivity allows for a temporal 'de-localization' as well: the problem can be dealt with or analyzed whenever the participant has the time, or feels like doing into it, without the constraint of a fixed and un-flexible schedule.

Fig.1: The CONNECTUS package

The standard version which includes: a vibration sensor, a pletismograph for studying peripheral blood circulation, a signal generator, a software package for visualizing and processing the acquired data, an introductory course in data acquisition and numerical processing, a set of proposed experiments, a web-connector with links to authorized information sources. The CONNECTUS package is fully exploiting modern hardware as well as virtual instrumentation and allows information transfer/exchange via the Internet.

The CONNECTUS platform was thought and conceived in a modular format that enables to set-up the infrastructural and informational base necessary to explore interactively the topic(s) of interest. These topics are initially selected and structured by the CCS specialists, and they also aid in coaching the teenager participants who could be working for his project in the comfort of their home. These topics and projects are structured by CCS in multimedia packages configured as an integrated **Personal Laboratory** (PL) which works when annexed to and installed unto a PC. Among these topics we mention here only a few: *"The heart: is it a chaotic oscillator?", "Can stress be diagnosed by monitoring the neuro-muscular electric activity"? "Are plants biological sensors?", "Technical diagnosis and the 'noise' ", "The meteo-sensitivity and the neuronal calculator"*.

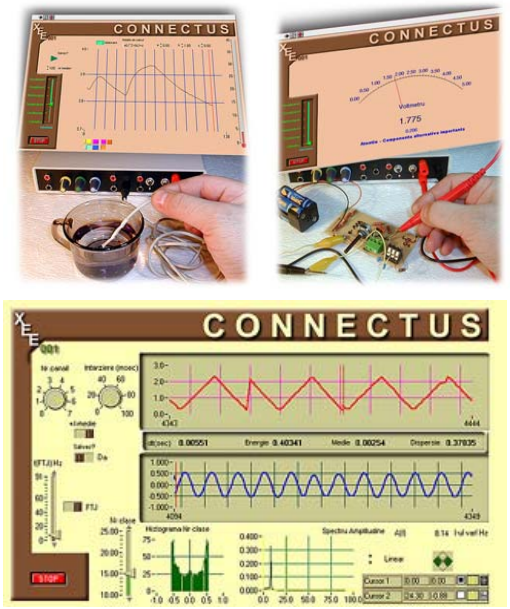

Fig. 2 Nature can be explored in the Personal Laboratory **(PL)**

These (and other) topics are not easy and may even seem pretentiously difficult and they do require a learning curve to be climbed by the participant. However, we must highlight that the CONNECTUS package has been designed and hierarchically structured in such a way that it eases the understanding of the problem by presenting it on levels corresponding to the degree of difficulty associated with the respective participant and with his/her skills and her/his background (e.g. primary school pupil, or secondary school student, or University student, or even MSc/PhD level). This structuring of the approach to the problem and the access to information motivate working in a team. The participants' complementary abilities and knowledge is a crucial factor in effectively 'gluing' the team together and building their team-spirit by self-assigning the responsibilities and tasks that cannot be done by other members and unto which the progress of the entire team may depend

These structured multi-level research teams can easily be formed:

- In the organized framework of educational institutions, e.g. high-schools, or scientific/'hobby' clubs dedicated to exploring a common passion or topic of interest. This can allow interaction at even a hierarchically superior level, e.g. connecting various students of a high-school with students from other high-schools in city-wide projects in which the participants may not necessarily know each other directly or study together in the same institution.;
- "Ad-hoc", by joining together participants which have the same basic interests or are passionate by a certain topic, and who may, e.g., be mobilized in a team by responding to an Internet-placed problem/advertisement related to the desired project;
- Single users of the PL.

In this way, the CONNECTUS user acquires knowledge and capabilities in a pleasant and useful manner, without having the constraint or the impression that he is "forced" to learn something, or to accumulate useless knowledge. Moreover, the team work definitely would develop the sense of responsibility and strongly stimulate the self-learning desire of the participants who would be interested in developing the know-how and the skills required to solve their task and advance their project.

"Live" image of a high school participant in the experiment "Plants as biological sensors" carried out in the NEXUS program. This particular project motivated the participants in understanding and deepening their knowledge in botanic, physics (diffusion phenomena, periodic and non-periodic oscillations, concentration piles, thermoelectricity, „noise"), mathematics (numerical methods and their application in signal analysis, functions, graphic representations, basic elements in fractal geometry, fundaments of biomathematics), electronics (preamplifiers, operational and instrumentation amplifiers), informatics and software programming (Matlab, LabView, Excel, Word, Photoshop, TP, C++).

Consequently, the information initially provided by the lectures at School, or by books, Internet or long-distance courses can now be practically applied with experimental verifications. PL orients the human attention towards Nature and its phenomena while encouraging human interaction and practical experiences, avoiding the well known 'engulfing' or isolation -addictive and yet not always fully satisfying character of the purely virtual experiences. As such, it helps to train and develop the young mind by closing a crucial feedback loop: from pure theoretical knowledge towards practical proof, through experimentation and understanding of the valid and applicable alternatives. Therefore, using the CONNECTUS package enhances the education and formation of the teenagers and encourages them to continually explore and apply this circle of know-how building in any other aspects of their life or in other projects they may encounter later by the entire team working for that specific project.

In conclusion, CONNECTUS is a true stimulant of the teenagers' innate discovery and creativity, acting thus as a 'motor' for their own work on the path of self-discovery and application of their ideas. It allows them to observe, ask themselves and among themselves, to collaborate interdisciplinary, to emulate the true spirit of responsibility and of teamwork. All these ultimately educate them in a new manner and also make them understand (by intrinsic participation) what means the new paradigm of Complexity and how one can contribute in structuring a Knowledge-based Society.

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