

SENSORS: THE MOTIVATION FOR LEARNING, TEACHING AND INNOVATING

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Abstract

Sensors are chosen as the focus of a new approach for learning, teaching and innovating. The fact that nowadays there are sensors based on all types of physical, chemical and biochemical principles, is the focus that brings all natural sciences and many technologies together.

The idea is explored from historical aspects, such as the difference of doing basic research nowadays and in the eighteenth century, but with emphasis on the recent trends, given by the popularization of personal computers and of Internet. The fundamental aspect played by people feelings on being motivated is considered, and the presentation explores the need for actions that change people attitude more than creating new courses or teaching techniques.

The aspect science-technology-society is approached; proposing a large educational program based on the use of existing sensors in schools, fairs and museums. Because there sensors that detect all types of natural phenomena they bring together all natural science and engineering disciplines, helping people to develop the ability to observe, compare and judge. As far as teaching practice is concerned, the use of sensors are proposed to be the basis of a science teaching program for all school levels and for continuous learning programs. It is discussed the fact that subject "sensors" can be approached at any level from the most elementary proportionality point of view up, to the most sophisticated nanotechnology, and data processing. Well designed sensors based, teaching program can take into account the particular aspects of interest of each community, however keeping a common focus on sensors, but with approaches rather different and adapted to specific characteristics. The role played by this program in each level of learning is listed in a tabular form considering the level, or category, the objective and resources and the expected results. The program proposed here is not a close proposal, but a reflection on an initiative that can have very positive effects on the interest of people for learning about science and technology, creating also new opportunities for business.

The perspective of associating the generation of wealth, with motivation for learning and innovating is discussed within the sensors program proposed. The first step along the lines suggested on this paper is given with the creation of the Laboratory of Innovation on Sensor Technology - LITS.

Introduction

There was a time when theory of phlogistic was used to support the industry of material transformation, specially metallurgy, and at that time, common people could imagine how the four elements that everyone could sense: air, water, earth and fire, were used in industry and in natural processes. The theory was confusing, but public conferences were regularly addressed to everyone, scientists, politicians, peasants, etc. They were all curious and trying to use this confuse theory to understand the natural world. The idea of the existence of atoms already existed, but chemistry had not been systematically organized.

Just before the French revolution (2nd half of 1700), it was Lavoisier that had the clearest perception that something was wrong and he started a systematic research, measuring carefully quantities that allowed him to relate the world of atoms with the manufacture of better metallurgical products.

If from one hand Lavoisier's great contribution created the basis of the chemical industry revolution, from the other hand the sophistication and the need of a systematic rational and structured approach made things much less attractive to people without the necessary background.

Natural sciences like chemistry, physics and biology have advanced to such a point that, even our best trained and most qualified persons, have a hard time in being able to imagine what happens in areas where he/she is not a specialist. Nowadays, the techniques used for measurements go from the large astrophysical quantities down to the atomic and nuclear scale. The so-called nanotechnology is based on lengths in the scale of one billionth of a meter and in concepts that violate every one common sense.

In this very complex world, the question of how can we motivate our population to understand science and technology, or at least attend to a conference on science and technology leaving the conference motivated, is a very hard one. It has been largely recognized that this is a major problem faced by all of us and it corresponds to the core question addressed at this conference.

The present paper intend to shine some light on this complex situation pointing out a general approach that involves all five sub-themes of the conference.

Focusing on the theme "Sensors", the first sub-theme science-technology-society is approached, proposing a large educational program based on the use of existing sensors in schools, fairs and museums. The second sub-theme, content areas corresponds to the core of what is proposed here, because there are sensors to detect all types of natural phenomena, bringing together all natural science and engineering disciplines. As far as teaching practice is concerned, the use of sensors can be the basis of a science teaching program for all schools and continuous learning programs. It is not obvious, but interesting to note that the subject "sensors" can be approached at any level from the most elementary proportionality point of view, up to the most sophisticated nanotechnology, and data processing. Concerning to assessment, one should consider that each community has its own needs, which can have the common focus on sensors,

but with approaches rather different and adapted to specific characteristics. Finally the history and philosophy of science is the aspect mentioned in the beginning of this introduction.

Measure, quantify and motivate

What really matters are the people's feelings, because, within people's feelings is where motivation "lives" and motivation is what makes people spend time and energy in doing something boring, like measuring and calculating. In 1987 the newspaper Toronto Star of the city of Toronto in Canada promoted a series of meetings on the theme "What We Want From Our Schools"[1]. The meetings had involved schoolteachers, administrators, businessmen and politicians.

Besides all the obvious conclusions of the difficulties and complains, one of the most striking was that society wants people that are able to communicate and able to relate themselves with other people. Relating to other people also means being able to write, read and judge, which frequently implies in having some background on language and ideas of proportionality, for example.

One can say that this is exactly what our schools are doing. However, the question of doing it in the most effective way is what matters. A suggestion of a new approach, in the framework of science and technology, is the aim of what is treated in the following paragraphs and sections.

Personal motivation is linked to someone's personality, but depends strongly on opportunities offered by the society, and also on challenges that people think they can overcome. Most people like to satisfy their curiosity, but also like to be rewarded for their contribution. The next paragraphs intend to show that sensors can be the focus of a new approach that will bring the motivation for people to learn about science, to quantify things and to generate wealth, creating a culture of innovation.

The decade of 1980 was characterized by the spreading of the use of personal computers and it can be considered the decade of the increase in the capacity of storing and processing information [2].

During the 90's the capacity of storing and processing kept increasing, but the availability of Internet was the important leap and that decade can be considered the decade of the popularization of the access to the information [2].

This first decade of XXI century already shows clear signs of the trend described above. The "stars" of the decade, most of the time have very small dimensions, microscopic in many cases, and are produced with a wide variety of technologies and materials, some of them discovered only recently. These new stars are the sensors that provide the information for the already fast, reliable and large capacity systems. The miniaturization and the evolution of informatics are the key facts that have created the new opportunity treated here.

In fact, defining sensor as an element that senses something, making the conversion to a measurable quantity, send us back to the Roman Empire, when devices to measure water consumption were already used. The differences now are the sensitivity, the varieties and sizes available, together with the huge availability of reading, storing and processing information at relatively low cost. One can say that the sensors are providing computers the capacity of hearing, seeing, smelling, tasting and touching the environment. In some aspects the sensors provide the capacity that goes far beyond the human possibilities.

Despite of the promising market for new sensors, there are already a great variety of sensors available and an increasing need to monitor things. The Romans could make mistakes of a few percent in their water control without problems, but nowadays, population has increased to a level that requires very tight monitoring for public services, such as supply of energy and water. Controlling air, water and soil pollution is becoming more and more critical, and a large number and better monitoring systems are a necessity. Many industries, public and private services, and individuals will have increasing benefits from the use of sensors. Therefore, this is probably one of the most promising fields for new enterprises and consequently for the so desirable innovations.

Technological Opportunities and Difficulties

The proprietary characteristics of sensors, i.e., the technology for each sensor depending strongly on final application of it, is an aspect that makes this field highly attractive for a country like Brazil. In fact, the country can rapidly become self sufficient on adapting existing technologies, even if mastering the technology of production of many sensors is not easily reached, or not even desirable. In fact, this aspect is similar to the situation of personal computers, or automobile industry, where the technology is very internationalized and interdependent, but in the case of sensors there are many possibilities of being self-sufficient.

The other important aspect is the variety of applications ready to apply adapted sensors, which include optimization and continuous control of water, air and energy. The benefits for the environment are limited only by our imagination. Accidents can be avoided by continuous monitoring the physical integrity of industrial equipment and reservoirs.

The technology of making sensors ranges from silk screen methods, with the so called thick film technology to the nanotechnology, so that, one can choose the most convenient technological level.

As an example, sensors based on fiber optics that are produced in Brazil, are obtained making small physical and chemical modification on the commercial optical fiber and they can monitor mechanical behavior of structures and equipment [3], quality of water [4] and bio-specific interactions [5].

This paper does not intend to discuss the technology, but to point out the need to develop a culture on sensors and to start soon to avoid missing the opportunities that are in front of our eyes. These opportunities will be available for people that catch the essence of this new wave.

At first sight the opportunities seem to be open only for first world countries, with a highly educated population, however, considering that microcomputers and internet are being incorporated at all levels of instruction, one can imagine that the use of sensors can also follow the same trend. In fact, it is more a matter of a new attitude than that of specific knowledge. People use well cell phones without knowing any detail of it and sensors are far less complex in many cases.

The variety of sensor types and operation conditions needed, opens possibilities that includes production, but applications and development of new technologies using the market available sensors is likely to be the a more promising aspect, as far as business opportunities are concerned.

Only for the technology of micro-sensors (MEMS) the projected world market is of US\$35 billions [6,7].

Sensors Learning and Teaching Program

Sensors are already incorporated in all living creatures. The human body is full of a variety of sensors, for example, the skin detects temperature, heat, humidity and pressure, the eyes detect light and movement, our nose detects some pollutants of air and the taste of water can indicate many pollutants. Some turtles, bees and birds use magnetic sensors to orient themselves [8]. All this is being used in a very effectively way, without any trouble in understanding details.

Therefore, a first aspect that an ambitious sensors learning and teaching program must consider is that we are copying nature and extending already existing possibilities. A second aspect to be considered is that at Lavoisier's time (2nd half of 1700), one individual could have its own laboratory, make fundamental discoveries and be a successful entrepreneur, however, nowadays fundamental discoveries are made by groups of researchers forming international networks and having first class, very expensive infrastructure. A third aspect is that this is a multifaceted program that can start at all levels at the same time, but must have a clear and motivating focus.

Under these aspects the program must bring up the consciousness of the role of sensors in understanding nature, the large variety of systems that already use sensors, the new opportunities open to people on learning and on generating new business with relatively low investment.

In that sense the authors have proposed the workshop "SENSORS: A Corrida do Ouro do Século XXI" promoted by ABINEE-PR (Associação Brasileira da Industria Eletro-Eletrônica), LITS (Laboratório de Inovação em Tecnologia de Sensores), TECPAR (Instituto de Tecnologia do Paraná) and UFPR (Universidade Federal do Paraná), sponsored by IFM-Electronic, IEL (Instituto Euvaldo Lodi), Renault do Brasil, PETROBRAS, Rede Paraná Autotech, Paraná-Tecnologia and MCT (Ministério de Ciência e Tecnologia), and supported by SMAR Sensores, SINAES-PR (Sindicato Nacional da Industria Eletro-Eletrônica), TURCK Sensores, CTA (Centro Técnico Aeroespacial), SIMEPAR (Instituto Tecnológico Simepar), SETI (Secretaria Estadual de Ciência Tecnologia e Ensino Superior) and FINEP (Financiadora de Estudos e Projetos) and organized by HAWK BRASIL, at Curitiba during the 20th and 21st of November of 2001. During that workshop the "LITS - Laboratório de Inovação em Tecnologia de Sensores" (Laboratory of Innovation on Sensor Technology) was officially created with the mission of disseminating the culture of sensors use in our society, develop sensor applications and research new sensor technologies. The LITS is planned to act on all levels of education and research, keeping a wide network of collaboration with schools of all levels, industries and government.

In order to fix some of the ideas presented the teaching levels involved and action are presented in a tabular format.

Category	Objective and resources	Results
Elementary	Dissemination of the idea and awake of curiosity. Schools laboratories, fairs and museums.	School children motivated to understand sensors. Common people curious to learn about sensors and its possibilities.
Technical Level	Train people on use and maintenance of sensors available. Technical schools & Companies	- Competence + knowledge of market. - Optimization of processes. Innovation of process & product
University Level	Qualify engineers and scientists in sensor technology and market. National and International Universities, Companies and Research Institutes.	Development of products and processes. Innovations with sensors including software, products and processes.
Professional Graduate Program	Business and Technical directed Research. National and International Universities, Companies and Research Institutes, including business and administration.	Development and adaptation of new processes and products. Innovation of products and processes, including managing.
Academic Graduate Program	Basic Research in Materials, Processes and New Concepts. National and International Universities, Companies and Research Institutes.	New advanced Technologies. Radical Innovation. Highly Technology Updated People.

This program must have a strong emphasis on the formation of networks with other research centers, universities and companies around the world. The sensors program is designed to create opportunities for people to grow as persons, learning an updated subject that opens opportunities for them, but also knowing other people, places and cultures. The dissemination of entrepreneurship and the capacity of generating Innovations are intrinsically linked to this view of sensors.

This is an ambitious project and several steps are to be overcome. As a result of consistent actions, an already constructed area of 200 m², was assigned to the LITS in the TECPAR (Instituto de Tecnologia do Parana) in Curitiba-PR. Paraná State Government already provided an initial budget of almost three hundred thousand reais, for infrastructure and equipment. An agreement on transfer of technology in sensors is already established with the CTA (Centro Técnico Aeroespacial).

As far as, the educational part is concerned the team involved is analyzing other programs already established. There are a number of very interesting isolated initiatives, but as for our knowledge there is no parallel in the world, to the global approach as proposed here.

At the University level, a specific degree similar to the French, Diploma de Etudes Scientific Superior-DESS on the Physique des Capteurs et Systemas de Mesure of Université du Paris VI, VII in collaboration with the Conservatoire de Arts et Metiers-CNAM, is under consideration to be implemented in Curitiba-PR. Similarly to the French system this shall be a new complementary partial degree directed towards training people for companies or for them to open their own business with a strong support of private sector. The international cooperation with exchange of students, professionals an opportunities for internship are being considered, together with the different and complementary realities.

Conclusion

The idea of using sensors as a focus for a new view of science and technology teaching, is based on developing the motivation due to the challenge the sensors pose to peoples understanding, and also because they may lead to new low cost and high profit business. From the point of view of public politics, there are enough evidences that society will depend more and more, on precise monitoring of consumption of energy and water and also on measurements of quality of air, water, soil and food.

A first step on creating a culture where people is motivated to learn about what happens around them, is given with the creation of the LITS (Laboratorio de Inovação em Tecnologia de Sensores). The authors hope this paper will stimulate new initiatives along the same line, and that this will form an effective network of learning, teaching and innovating.

References

- [1] – Report card on Our Schools. A Reprint of a Six-Part Series. Published as Special Report of Toronto Star. Copyright(c) 1987.
- [2] - Paul Saffo "***Sensors: The Next Wave of Innovation.***" www.acm.org/cacm/FEB97/saffo.html Institute for the Future, (1997)
- [3] – Homola Jiri, Sinclair S. Yee, Gunter Gauglitz, "***Surface plasmon resonance sensors: review .***" Sensors and Actuators B, **54**, (1999) 3 –15
- [4] - Azedine Charef, Antoine Ghauch, Patrick Baussand and Michel Martin-Bouyer, "***Water quality monitoring using a smart sensing system***", Measurement, **28** (2000) 219-224
- [5] - C. K. Y. Leung, "***Fiber optic sensors in concrete: the future?***", NDT & E International, **34** (2001) 85-94
- [6] - Guido Tschulena, "***Market Analysis for Microsystems 1996 – 2002***" - www.sgt-sensor.de/NEXUS.html
- [7] - Azedine Charef, Antoine Ghauch, Patrick Baussand and Michel Martin-Bouyer, "***Water quality monitoring using a smart sensing system***", Measurement, **28** (2000) 219-224
- [8] – Kathryn Brown, MAGNETORECEPTION:Animal Magnetism Guides Migration
Science 2001 October 12; 294: 283-284

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