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INTRODUCING THE MATERIALS WORLD MODULES IN MEXICO: THE CHIHUAHUA PROJECT

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ABSTRACT

The Spanish translation, adaptation and implementation of the Materials World Modules Program in Chihuahua, Mexico, are reported. This educational program has been developed at Northwestern University by a multidisciplinary group led by Prof. RPH Chang. It is designed for high-school level and aims to enhance knowledge and motivation in basic sciences. The article describes the training of teachers in the methodology of the modules, the manufacture of so-called experimental kits and the work with students in several cities of Mexico. Statistics on the growth of the project, as well as on students' gain of knowledge, are presented.

1. INTRODUCTION

The technology market is currently the scenario where the leading countries of our globalized world are defined, and the most important means to win this competition is scientific knowledge. The three main poles of development, namely North America, Europe and Asia, devote considerable resources to research and scientific education. Latin America has some state-of-the-art scientific poles, but overall it is lagging behind in this global competition. Actions are urgently needed to encourage scientific and technological growth in Latin America.

The present article describes the development of a specific project in science education developed in collaboration between Mexican and U.S. academic institutions. This is the introduction of the Materials World Modules (MWM) system in Chihuahua, Mexico. MWM were originally established at Northwestern University (NU). MWM system is aimed at high school education and its basic premises are the integration of science and the incorporation of design activities in the teaching-learning process.

2. SCIENCE, TECHNOLOGY AND ECONOMY. THE USA CHALLENGE.

The economic level of a country is directly related to its scientific and technological level. The international competition in this field is very intense. Table 1 compares the technological balances of payments of Japan and USA[1].

Table 1. Technology balances of payments in Japan and USA, 2006.

Country	Exports (MU$D)	Imports (MU$D)	Ratio
Japan	20,448.8	6,065.3	3.37
U.S.A.	75,380.0	35,479.0	2.12

Figure 1[2] shows the fraction of global domestic product (GDP) devoted to research and technological development in various countries, including Japan and the USA. The relationship between the balance of payments and % of GDP for science is not simple, but the comparison between the data of Table 1 and those in Figure 1 does suggest a true correspondence: in the long term, support to science significantly benefits competitiveness.

Figure 2 [3] shows the numbers of researchers in selected countries. Apparently, we witness the moment when China reaches the U.S. in some key indicators of scientific activity.

For the U.S., developing ambitious programs in research-development-innovation is a vital issue. Maybe the best example of corresponding actions at country level is the so-called National Nanotechnology Initiative[4] which spends about 2 billion U$D a year.

3. THE MWM PROGRAM

In the long run, science education, including basic and high-school levels, shall determine whether or not the effort in science bears fruit. In this context, the MWM Project[5] forms a major science education program sponsored by the National Science Foundation (NSF). The MWM program was established at NU by a multidisciplinary group led by Prof. R.P.H. Chang. The project began in 1994 when it received initial support from the NSF. It is a modular system aimed at high -school education. Presently it is applied in virtually every state in the US and has proved in practice that leads to significant increases in the qualification and motivation of students towards science subjects and mathematics. (See the section "Assessing Learning" in the MWM Program website).

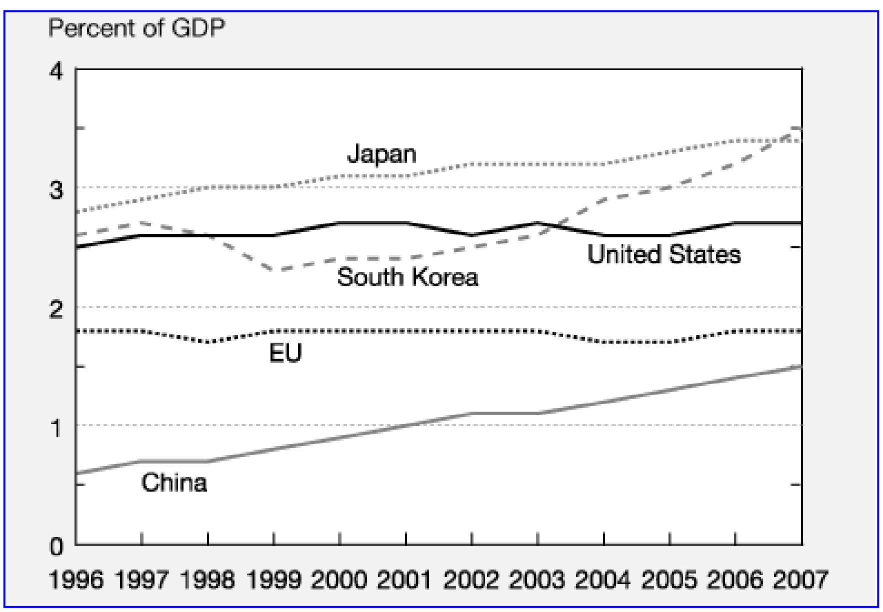

Figure 1. R & D Expenditures as share of Economic output. Selected countries: 1996-2007.

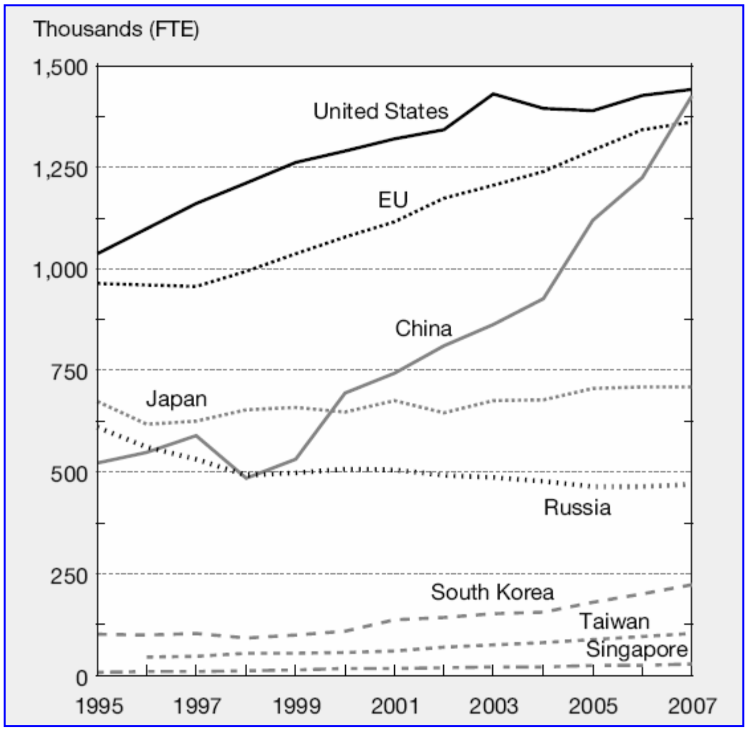

Figure 2. Number of researchers in selected countries: 1995-2007.

The challenge taken up by the group of Prof. Chang has been to integrate a package of current trends in the so-called "hard sciences" (now integrated in Materials Science) with the state of the art in Science Education

The Modules incorporate the basic ideas of *constructivism* of Piaget[6,7] and *significant learning* of Ausubel[8,9,10,11]. Each module begins with the so-called "Activities", which take between 8 and 10 hours of class and concludes with a "Project Design", about 4 to 6 hours. All work is based on scientific experiments and / or technology. The teacher does not expose, but directs research by students. Students predict, observe, experiment, read, compute, expose, discuss, design, redesign, arm, disarm, play, go through moments of confusion and finally, through their collaborative work, they discover truths of nature and learn to transform the world for good. In the search for truth through the experiment, reasoning and discussion, students are faced with the need to adjust and / or rearrange their initial representations. They discover for themselves that science is not to accumulate new knowledge over those already owned, but that learning is a dialectical process of removing (sometimes dramatically) the previous model and replacing it with a new, more inclusive, one.

Both the Activities and Projects are developed by collaborative work of students. A student changes the mindset of another and vice versa. This style emphasizes and leverages the social nature of learning, one of the main theses of Vygotsky[12,13].

The modules work in groups of 20-25 students with two or three teachers per group. The ethical, epistemological, and behavioral objectives of teachers for their students[14,15], as well as so-called multiple intelligences[16,17] can be treated in a personalized way.

The MWM program forms the intersection of advanced technology research and education. Figure 3 depicts this intersection.

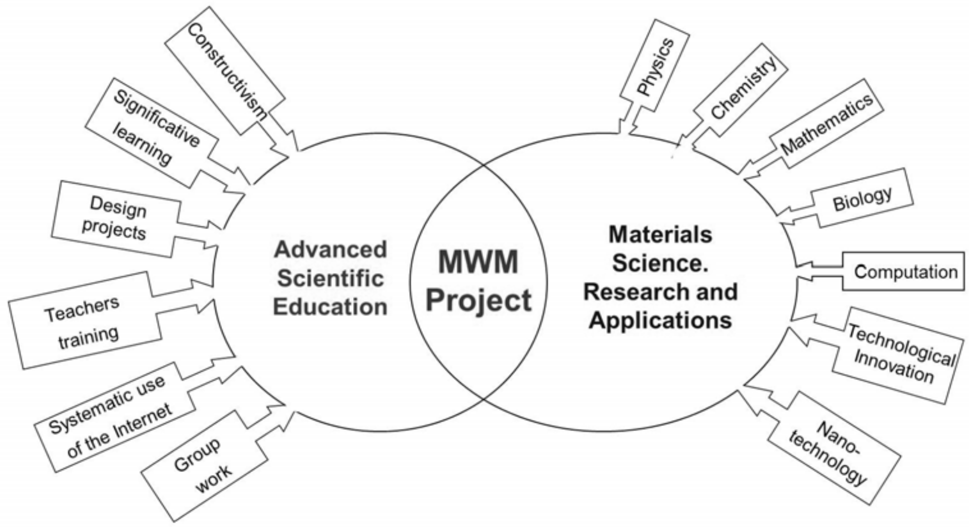

Figure 3. The MWM represent the intersection of integrated approach to scientific research and advanced scientific education.

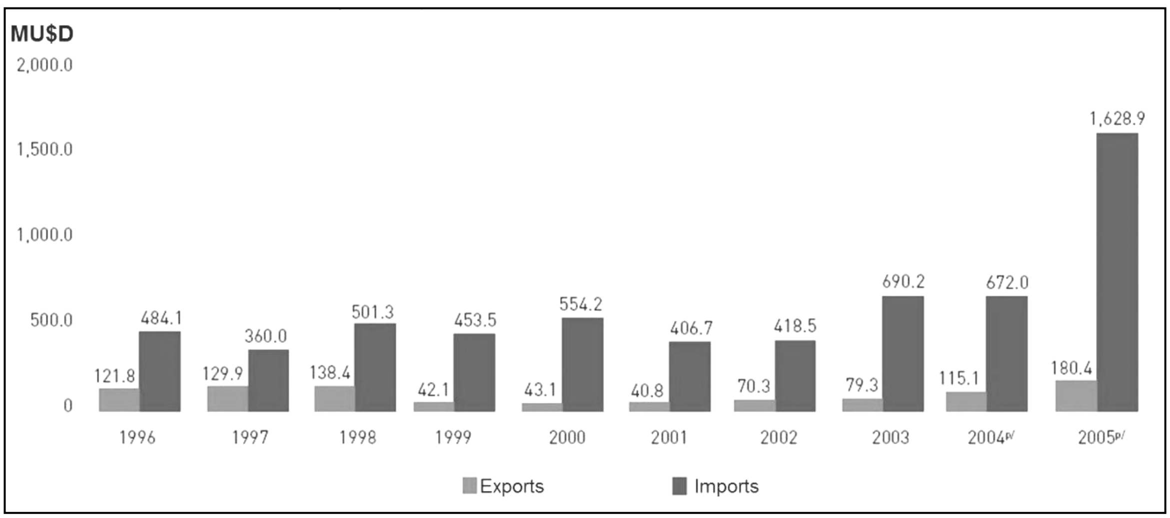

Figure 4. Technology balance of payments in Mexico: 1996-2005.

4. THE MWM-MEXICO PROGRAM. THE CHIHUAHUA PROJECT.

Are MWM-type programs required in Latin America? No less than in USA. As an example, Figure 4 shows the technological balance of payments of Mexico in recent years[18]. Compare the data in Table 1. Mexico buys nearly 10 times what it sells of technology.

The idea of a MWM-Mexico Project arose from the local and international relationships of the Centro de Investigación en Materiales Avanzados (CIMAV). At local level, in Chihuahua, CIMAV had been developing basic science advice to secondary education. At international level, thanks to exchanges among national societies of researchers in materials science, CIMAV knew about the MWM Program generated at NU. Concatenation of the two levels of collaboration was a natural event and hence the proposal was designed to translate the modules into Spanish and introduce them in Mexico. The project started in Chihuahua, the focus that generated the initiative.

The MWM-Chihuahua Project has been developed by an inter-institutional group, whose main implementers are the authors of this article. NU has provided advice and general support. This includes conducting training workshops for teachers, accessibility to the original manuals and kits for the first application groups. Six investigators from CIMAV have conducted and technically advised the hundreds of high school level teachers involved in the program. These researchers have translated the manuals.

Pairing and general coordination with upper secondary education system of Chihuahua has been charged with the representatives of the Ministry of Education, Culture and Sport (SECD).

Table 2 shows the modules that have been put in place and operate normally in Chihuahua.

We illustrate the adaptation of the Modules to the conditions of Mexico by the example of the Biosensors Module. This module explores the peroxidase and oxidase enzymes: their role as catalysts and their application in biosensors for the determination of glucose and cholesterol. The original module developed and distributed by NU uses enzymes purchased from commercial laboratories. A stage in the adaptation process of this module was to replace commercial oxidase and peroxidase by the same enzymes, obtained by students from natural sources. The sources used today are the (very Mexican) spicy radish and "tomatillo". The current module is of greater educational value and costs less than half the original.

Table 2. Modules introduced in Chihuahua. Design Projects associated with each Module are included.

Module	Design Module
Biodegradable Materials	Drug delivery device
Biosensors	Cholesterol and glucose biosensors
Composites	Kite, fishing pole
Concrete	Roof tile, super resistant concrete
Sport Materials	Super-elastic ball, miniature golf
Introduction to Nanoscale	Nano-induced geyser

Figure 5. Matthew Hsu (NU) leading the Workshop on "Smart Sensors." Teacher Alejandro Martinez as an interpreter. Ciudad Juarez, December 2008.

4.1 Teachers Training

The teachers training program began with a group of 45 teachers in Chihuahua City, in 2005. These teachers received a so-called "Diplomado" level in the MWM Methodology, with advice from NU. Figure 5 shows a moment of the Workshop on Intelligent Sensors, taught by Prof. Matthew Hsu (NU). Further growth of the program is based on the skills gained by trained teachers in the MWM methodology.

4.2 Modules Operation in Practice

The SECD indicated the operation of the Modules to different high-school level subsystems of the state. This Ministry guaranteed printing of manuals, sponsored the manufacture of kits, allocated teachers time and ensured the necessary infrastructure. The schools made the calls, promotion and registration of students and coordinated the successful operation of the modules.

5. RESULTS

5.1 Participation Statistics

The MWM project has grown steadily since its inception in 2005. Table 3 shows the number of new teachers who have been trained in the MWM methodology per year.

Table 3. Trained teachers. Years 2005 – 2010

Scholar year	2005-2006	2006-2007	2007-2008	2008-2009	2009-2010	Total
Trained teachers	51	80	81	35	62	309

Figure 6 describes the growth in the number of students taking the modules.

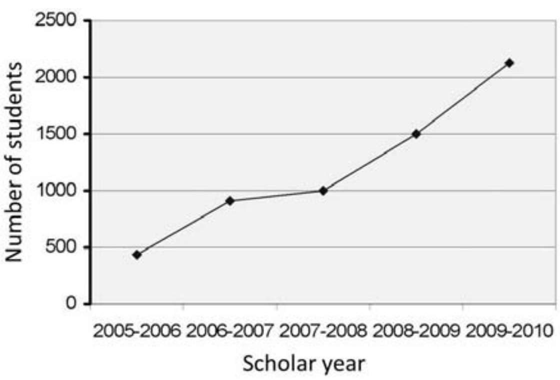

Figure 6. Number of students who have completed the MWM modules per year.

Figures 7 and 8 are photographs representative of a typical day in a workshop MWM. The kids learn while having fun.

Figure 9 shows the distribution of the Program throughout the state of Chihuahua. The part of the state where the "MWM" logo is not visible, is the well-known desert of Chihuahua. The western part of the state is the Sierra Tarahumara, home of the famous Copper Canyon. Up there the modules are active.

Figure 7. Science is fun. Workshop on Concrete. On the board, the question: "why the cement hardens?"

Figure 8. Simulation of a blood cholesterol test. Biosensors module.

5.2 Statistics relating to gain of knowledge

The initial activity of each module consists of an assessment of the starting level of knowledge of the students, related to the topic of research. Each module ends with another assessment, equivalent to the initial one, applied just after the Design Project. The MWM organization standardizes the questionnaires and controls the consistency of their application in schools. Figure 10 is probably the most important of this article. It shows the comparison between the combined histograms of all pre-modules and post-modules tests for the 6 modules applied throughout the state of Chihuahua in the period 2005-2010. The global gain of knowledge is significant.

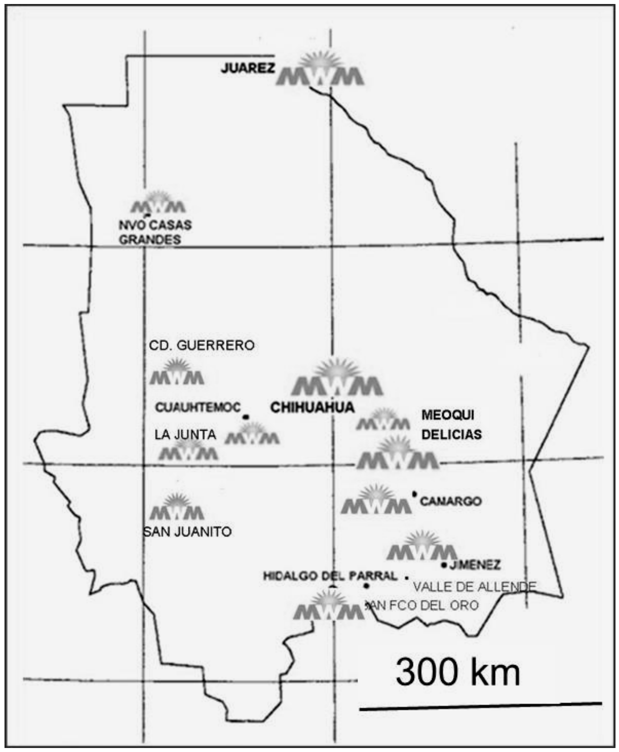

Figure 9: Expansion of the MWM in the state of Chihuahua.

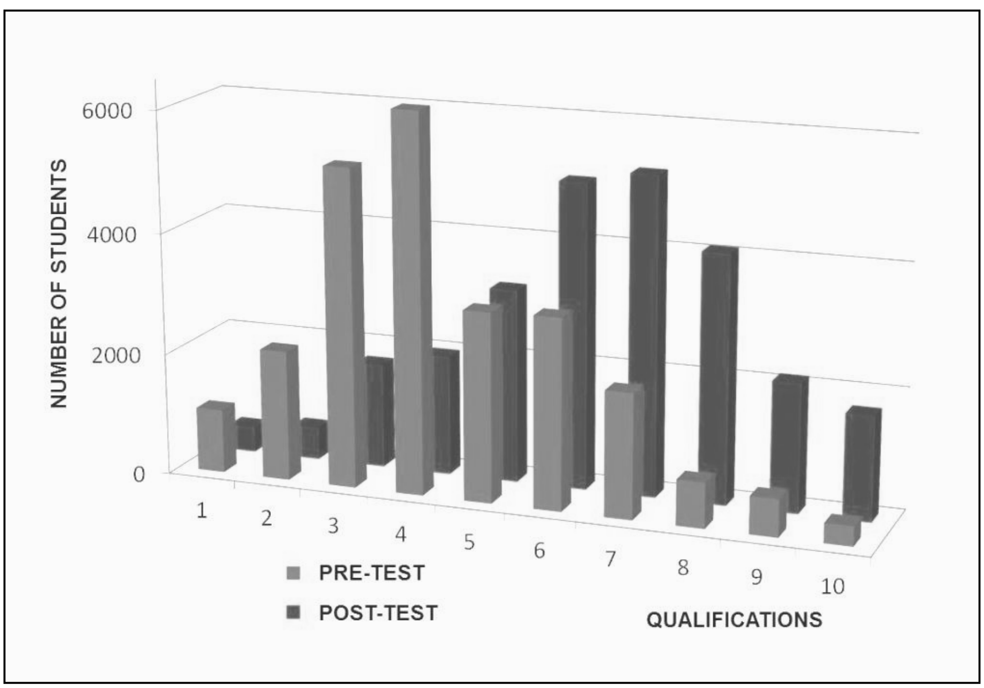

Figure 10. Chihuahua. Assessments obtained by students before and after attending the MWM modules.

5.3 Impact and/or regional implications

The introduction and operation of the MWM program in the state of Chihuahua has a significant impact on the region and begins to affect other states. Some revealing manifestations of this impact are:

- Reorientation of students toward science and technology careers. Table 4 shows a selection of results of surveys conducted at the end of MWM cycles.
- Changes in the attitude of teachers and students in their daily classes. After teaching the MWM workshops, neither teacher nor the students are the same in their regular courses.
- Dissemination of science and knowledge in the population, at local and national scales. Change in popular perception about the usefulness and accessibility of science.
- Attention to science education in historically underserved areas. Certainly, the most remote communities are the most grateful to the MWM program.
- Outreach to other states. In the state of Puebla, a group of teachers has already been trained in the MWM methodology MWM. Work with students begins in 2011.

Table 4. Results of surveys of students who have completed the Modules.

Questions	Answers (%)		
	Yes	Indifferent	No
Do MWM improve your progress in mathematics, physics, chemistry and biology?	63	35	2
Do MWM motivate you to reassess the scientific and technological knowledge?	74	25	1
Do MWM incline you to consider a career in science or engineering?	62	35	3

6. CONCLUSIONS

The Spanish version of the MWM program has been prepared, applied and tested successfully. It is ready for widespread use in other parts of Mexico and Latin America. It is offered to sister countries in the same non- profit spirit that Professor Chang has given the MWM program to Mexico.

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