Abstract – The Pequeños Científicos (Little Scientists) program is a K-6 initiative for the development of scientific and technological competencies of Colombian children. Over the past 5 years, Pequeños Científicos has developed and evaluated some teacher training, strategic planning and assessment tools for the institutionalization of the program in the educational institution. Currently, achievements include the development of an organized evaluation system and the organization of developmental nucleus around the country. Stakeholders and governmental institutions have acknowledged and recognized the initiatives of the program for the improvement of science and technology education, and its links with the development of scientific literacy. Implications of the program for engineering education, and citizen’s development for the XXI century are discussed.

Index Terms – evaluation system, K-6 engineering education, teacher training, strategic planning.

INTRODUCTION

Each day, it becomes more evident how scientific development motivates great transformations in society, as well as how these changes imply a growing need among the planet's citizens for training and education.

One concrete result of these transformations is the expansion of the concept of literacy. According to UNESCO [1], scientific and technical literacy, in its broadest sense, transcends the ability to read, understand and write about science and technology, without underestimating the importance of these. Scientific and technological literacy includes the ability to apply scientific and technological concepts to life, work and culture, which make up society, and thus an individual's context. As such, it includes attitudes and values which allow one to discern, and make decisions about the appropriate use of science and technology.

Likewise, and motivated by this same need, a number of documents have been produced, proposing certain standards which specify what must be taught, and what must a citizen in the 21st century know regarding science and technology [3], [4], [5] and [6].

In contrast, teachers who practice today, as well as teacher trainers, were educated within a paradigm and within a culture in which science and technology didn't play such a central role as they do today. One consequence of this situation is the little emphasis placed on scientific and technological education for children. Likewise, pedagogical strategies are fundamentally based on the transmission of information to be learned by memorization. Nevertheless, an overview of the standards mentioned above reveals that scientific and technological literacy involves the development of competencies, of learning and problem solving processes which can hardly be achieved through the mere transmission and memorization of information. An example of this is biology, where the design of experiments requires scientific and mathematical abilities, and likewise, physics requires the ability to identify and solve problems. It is particularly important to pay heed to ICT (Information and Communication Technologies), since these provide a foundation for the current transformation undergone by our society [7], [8].

In the midst of this situation, interest for scientific and technological careers is in decline, which doesn't contribute to the development of ways to respond to the challenges of a knowledge-based society where scientific and technological development is a core element of a nation's competitiveness within the context of increasing market globalization.

This article briefly outlines a private nation-wide initiative developed in Colombia in which Engineering Faculties from some of the top ranking universities in the country have committed their efforts to contribute to the transformation of scientific and technological education.

ENGINEERING, SCIENTIFIC AND TECHNOLOGICAL LITERACY

Engineering schools have participated in scientific and technological literacy programs through a varied range of approaches. While some schools have involved themselves to
the fullest, some others have had a difficult time finding sustainability and relevance in their participation.

From an engineering school’s perspective, K-12 education, though valuable, is oftentimes assumed to be the responsibility of other actors in society, such as public and private schools, as well as the government. However, this situation has undergone dramatic changes in the last decade, for the following reasons among others:

1) The declining interest among the young for scientific and technological careers, often due to the little interest incited to them by their teachers. This leads to a decline in the quality of University applicants.

2) The difficulties new applicants face in college math, science and technology are, some times, the result of inadequate education systems for their first 12 years of studies. This is in turn reflected in high desertion levels and in the underutilization of resources for the training of engineers and scientists.

3) The growing importance of science and technology, of scientific and technological development, for which the training of scientists, engineers and PhDs does not suffice, there is also the need for general scientific and technological literacy among all of the citizens.

4) A clear awareness of the dramatic changes that will take place in the following decades propelled by scientific and economic progress, as well as their impact on society and on quality of life within it. The fact that in order to face this situation there is a need not only for scientists and engineers, but also for citizens who are sensitized to this issue, and are capable of taking advantage of technology, fostering productivity and competitiveness.

5) The germination of a new vision on research and development models, leaving behind the linear model which pretended to apply the results of scientific research conducted within universities and research centers [9]. Within this new vision, the citizen plays a fundamental role from the workplace. It is here where opportunities for improvement and innovation are detected, if the citizen has been adequately educated in science and technology.

6) The increasingly urgent need for sufficiently informed citizens to participate in the great decisions of their time and their society regarding the use of science and technology, and their growing impact over the planet [10], [11].

The importance of engineering schools in K-12 education is made especially evident through the growing number of initiatives, statements, programs, conferences, articles, books and projects in which the participation of engineering schools is not only requested and justified, but portrayed as an example.

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These issues have awakened interest among a significant number of Universities which have developed programs aimed at underwriting education in science, math, engineering and technology (known as STEM in the USA), of which further information may be found on the World Wide Web. Furthermore, academic organizations such as IEEE, ASME and CDS have expressed through statements and actions the importance of this initiative [12], [13].

Similarly, interest for K-12 programs has climbed to the topmost educational levels. One document in particular [14] justifies and promotes the participation by researchers with PhDs in science and engineering in STEM initiatives at the K-12 level, that is very much likely, the Pequeños Científicos' initiative, for scientific consulting.

Through a broadened interpretation and a systematic vision of a country’s development, it is clear that merely training engineers at every level, together with the construction of knowledge through high level research is insufficient to guarantee a nation’s scientific and technological development. [15] For this reason, supporting and leading activities related to the citizens’ scientific and technological literacy is part of the mission of any Engineering School. Not to do this means leaving the job half done.

HISTORY AND PRESENT OF PEQUEÑOS CIENTÍFICOS PROGRAM

In 1998 the Lycée Français Louis Pasteur in Bogotá began implementing the French program “la main à la pâte”, which promotes inquiry as a learning strategy for science and technology in primary school. Several targeted actions began this year in the form of scientific consulting, aimed at supporting this proposal, but it wasn’t until the year 2000 when the Colombian science and technology literacy program has its formal beginning.

In this way, and by request from the French school, Los Andes University accompanied every step of the program in its first years. In view of the evident results of the program in terms of the development of observation, experimentation, communication and argumentation skills, Los Andes University, in association with the Lycée Français in Bogotá, French cooperation, and the interactive science museum MALOKA, decided to begin a program with nationwide ambitions in late 2000. They began training and accompanying elementary school teachers in 2001. Later on, a group of schools, with a complex socio-economic context, under the name Alianza Educativa (Educational Alliance) implemented the pilot for this innovation.

Promising results have entailed that the program has expanded and the number of partners has rapidly grown. This is how, in the year 2005, the Colombian program earned, together with the Valle Imperial program in California, USA, the
国际奖励科学素养的地球儿童，其评委会由世界上最受认可的科学院院长组成。

现在，Pequeños Científicos项目已经在全国范围内推行，National Academy of Science已经加入该活动，其中包括该国一些最负盛名的大学。

同样，该项目已经设法将其定位为发展中国家的参考点。其中与其他国家进行密切合作，其中包括美国、墨西哥、巴西、阿根廷和智利，而且它与许多其他项目在其他国家进行永久性交流。

作为全国性的项目，它一直由Los Andes大学的工程学院领导。该项目的参与成员有助于定义参与学校科学和科技素养的政策。

企业家和基金会对促进科学和科技素养感兴趣，将其作为国家发展的一个必要性，已经参与了这项倡议，作为他们社会责任项目的一部分。

**MISSION OF THE PROGRAM**

Pequeños Científicos项目旨在促进和贡献于科学和技术学科教学和学习的改进，男孩、女孩和年轻人在哥伦比亚。通过引导课堂中的探究，合作工作，质量保证策略和扩大覆盖，该项目发展科学和科技素养、沟通能力和公民价值观。

更多信息可以找到在：www.pequenoscientificos.org

**NATIONAL ORGANIZATION FOR THE INITIATIVE**

该组织的哥伦比亚项目已经根据其需要进行建模。特别是，该计划处于从小规模的实验项目向较大规模的项目过渡阶段。它寻求在科学和科技学科教学中进行教学改革，以一种课程策略为基础，这不仅仅与我们知道的人类思维有关，而且也与科学和科技的本质有关[16], [17]。

以下图解概述了该项目的一般组织：

National Academy of Science，MALOKA互动科学博物馆，法国卢森堡法国路易巴斯德中学，Los Andes大学和Alianza Educativa协会，得到National Education Ministry和Empresarios por la Educación（Entrepreneurs for Education）Foundation的支持

国际上，与美国、法国、阿根廷、智利、巴西、委内瑞拉和巴拿马的类似项目保持着密切的合作关系，这些项目属于IANAS（国际科学院联盟）和支持来自法国对拉丁美洲的合作。

在每个地区，包括首都波哥大，在这网络中，包括波哥大，麦德林，卡塔赫纳，伊巴格，马尼萨莱斯，布卡朗加和莱蒂西亚。图2说明了项目的当前范围。

在这一方式，该国的八所大学在这个网络中合作，这个网络包括波哥大、麦德林、卡塔赫纳、伊巴格、马尼萨莱斯、布卡朗加和莱蒂西亚。图2说明了项目的当前范围。

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TABLE I

PEQUEÑOS CIENTÍFICOS COVERAGE

<table>
<thead>
<tr>
<th>City</th>
<th>Children</th>
<th>Teachers</th>
<th>Schools</th>
<th>University Leader</th>
<th>Sponsors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bogotá</td>
<td>16,480</td>
<td>412</td>
<td>28</td>
<td>UniAndes, UPN,</td>
<td>GAS Natural</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>UNAL</td>
<td></td>
</tr>
<tr>
<td>Manizales</td>
<td>1,760</td>
<td>44</td>
<td>12</td>
<td>U. Autónoma de</td>
<td>Fundación Luker,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Manizales</td>
<td>ExE</td>
</tr>
<tr>
<td>Ibagué</td>
<td>1,920</td>
<td>48</td>
<td>11</td>
<td>U. De Ibagué</td>
<td>ExE</td>
</tr>
<tr>
<td>Medellín</td>
<td>1,840</td>
<td>46</td>
<td>21</td>
<td>EIA, UNAL</td>
<td>Colegios Privados</td>
</tr>
<tr>
<td>Cali</td>
<td>4,120</td>
<td>103</td>
<td>11</td>
<td>ICESI, UniValle</td>
<td>Comfandi, ExE</td>
</tr>
<tr>
<td>Bucaramanga</td>
<td>160</td>
<td>4</td>
<td>1</td>
<td>U. Autónoma de</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Bucaramanga</td>
<td></td>
</tr>
<tr>
<td>Barranquilla</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>UniNorte</td>
<td></td>
</tr>
<tr>
<td>Cartagena</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>U. Tecnológica de</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Bolívar</td>
<td></td>
</tr>
<tr>
<td>Leticia</td>
<td>20</td>
<td>1</td>
<td>1</td>
<td>UNAL</td>
<td>Colegios Privados</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>26,280</strong></td>
<td><strong>609</strong></td>
<td><strong>85</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

PRODUCTS OF THE PROGRAM

This program, known as Pequeños Científicos, seeks to transform science and technology education by means of activities among which the following are most salient: Structured training and follow-up for school teachers (intensively during the first year’s work); production and supply of kits for experimentation work in the classroom; accompaniment to school management.

THE QUALITY MANAGEMENT SYSTEM

The growing size of the national program, which has doubled in coverage each year, has led to the development of a management system under the norm ISO 9001:2000. The system standardizes the structure for teacher training and follow-up, the evaluation system, and the production of materials, advancing in the consolidation of the program based on the Capacity Maturity Model proposed by Carnegie Mellon University.[18]

In response to the program’s national coverage, the management system can be found in an internet portal, to which participating universities have access. Within this space, the authors of different articles, reports and files for documenting the process, allow for systematic coherence and visibility in their body of work throughout the different regions.

THE EVALUATION SYSTEM

As part of the organizational structure as a whole, a national evaluation system has been developed which is currently in its national implementation phase. The system covers three dimensions:

- Quality
- Coverage
- Consolidation

Within each of these dimensions, a series of instruments and indicators have been developed which seek to allow for the monitoring of fundamental variables in the program. Among those aspects worth mentioning for each dimension are the following:

Quality: The learning environment, the perception of science developed by this type of program, and the civic and coexistence competencies promoted by it are evaluated.

Coverage: As illustrated by Table I, coverage relates to the number of children, teachers and institutions, which has grown exponentially.

Consolidation: Some observable evidence is examined to estimate the capacity of a nucleus/school to sustain the program once the training and intensive follow-up phase has concluded.

THE PROGRAM’S INSERTION IN THE UNIVERSITY

The importance of the articulation of K-12 education and higher education in science and technology has led to the creation of spaces which answer to the following strategies:

1) Contribution by University Professors of a number of hours devoted to teacher training on their specific subject. For this purpose, these professors receive training in the use of inquiry as a pedagogical strategy, which in turn promotes improvements in University-level teaching.

2) Development of projects aimed at producing better experimentation materials for children within the framework of academic projects for University students.

3) Voluntary participation of students in class accompaniment as scientific advisors.

4) Design of continuing education courses for school teachers in pedagogical and disciplinary subjects.

5) Research projects for education groups within the program’s framework.

6) Creation of graduate courses in education in relation to the teaching of science and technology, using the program in schools as a living laboratory.

Each of these strategies brings with it benefits for the universities involved in each region in terms of quality, social context and research. In particular, the creation of a social responsibility program with high impact and recognition can influence in the long run the number of candidates for scientific and technological careers. Furthermore, it induces reflections on the participating professors about their own pedagogical practice. It brings the students the possibility of approaching social problems through the educational system,

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since the program largely takes place within the framework of communities undergoing great difficulties. Finally, it contributes to the construction of the capacity for innovation and the development of scientific and technological literacy of the citizens.

CONCLUSIONS AND PERSPECTIVES

The Colombian program has managed to demonstrate the viability of a small scale scientific and technological literacy initiative creating alliances among key sectors in every society: government, the academy, the business sector and schools.

It is possible that only this type of alliance can effectively transform educational systems facing great difficulties, within the framework of a country with tremendous problems, including a lack of financial resources to carry out this type of transformation.

It is precisely this structure, involving different actors in society, which has deserved the Colombian program international recognition, within the larger context of a great international initiative led by the world’s academies of science.

All of these achievements and benefits mentioned above have entailed that the Pequeños Científicos program must challenge itself continuously, such as developing a management system capable of maintaining the program’s quality even in the midst of a rapid expansion phase, and to allocate the necessary human and financial resources to sustain the program. Another challenge lies in keeping up with the state of the art in each of the program’s activities, as well as maintaining the interest and commitment by government agencies. This last aspect is crucial, keeping in mind that administrative changes at the end of a presidential period imply great policy changes for some countries.

REFERENCES