Assessing and Developing Socio-Emotional and Communicative Competencies in a Pre-college Engineering K-6 Program

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Abstract – The Pequeños Científicos (Little Scientists) program is presented along with its pedagogical strategies to achieve scientific and technological competencies development in a K-6 classroom. The role of pre-college engineering education in the development of citizenship, and scientific literacy is stressed. Implications of the program in the development of socio-emotional and communicative competencies, and its links with the development of competent and scientific literate citizens for the XXI century are suggested. A qualitatively research focused on the design of an assessment pen and paper tool for socio-emotional and communicative competencies is presented. Results led to the construction of a self-report test focused on the constant evaluation of children development and classroom atmosphere. Implications for the assessment and improvement of pedagogical strategies in K-6 engineering education are suggested.

Index Terms – Assessment tools, K-6 engineering education, qualitatively research, socio-emotional and communicative competencies development.

Pequeños Científicos (Little Scientists) is an Universidad de los Andes school of Engineering initiative, intended to introduce into the country’s educational contexts a set of pedagogical strategies for the teaching and learning of science and technology. It bases its core approach to education in inquiry based learning, cooperative learning and, hands on -minds on activities by which children and their teachers are empowered to the joint construction of scientific knowledge as well as scientific, technological and socio-emotional competencies. Working in a K-6 curriculum, Pequeños Científicos has evolved from a pilot study in five low SES schools in Bogotá, to a program with more than 16,000 children, 400 teachers and 80 schools, in six of the mayor cities of Colombia. Along with this growth in coverage, the program has also evolved in its organizational, educational and evaluation systems focusing on the quality of the educational practices and in the consolidation of schools that have adopted the program as one of theirs core educational initiatives.

As a program, Pequeños Científicos emerges from the initiative of a school of engineering due to the acknowledgment of the role that undergraduate and graduate, science and engineering schools could play in the scientific literacy education of a country. Scientific literacy, according to NRC standards [1] and the American Association for the Advancement of Science (AAAS) Benchmarks [2], stands for what the general public ought to know about science, and for how they are able to experience the understanding of the natural world; apply scientific process and principles in personal decision making, engage in public debates around science and technology, and apply scientific and technological related knowledge, understanding and skills to improve their economical, social and personal well being. Also, scientific literacy in Colombia, as well as in the entire world, is a must for the growth of our societies. It allows people to critically engage in decision-making processes of their every day life. From how to choose your breakfast, to how population growth affects our everyday life, people must use and develop their scientific and technological competencies to understand scientific issues affecting theirs life’s, as well as use and develop their socio-emotional and citizenship competencies to effectively engage in democratic process for the decision making whit a critical sense.

Giving this context, the role of engineering and science schools and faculty in K-12 education could be seen as investment in the scientific literacy development of the students, to increase the probability that children will became interested in pursuing academic careers in scientific fields, or getting involve in socio-scientific decisions in their communities from their particular role on society,. Both actions that will translate into an improvement of the economical, scientific and technological development of a society. In addition, numerous studies had shown that Universities and particularly, science and engineering schools and faculty involvement in K-12 education could produce a positive impact on both the elementary students and teachers’ science understanding and competencies development. At the same time, undergraduate and graduate students and schools views of scientific inquiry, science teaching and learning, and cooperative learning in the scientific domain could be
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Strategic planning workshops and assessment, allow institutions to plan and development a support network for teachers that are introducing changes in their pedagogical practice, while evaluation and assessment conducted by the program are constantly directed towards the observation of children, teachers and institution changes and development, providing them whit information and feedback about their practices.

Working inside this schema, Pequeños Científicos has evolve from a pilot project with five low SES institutions in Bogota, to a program with more than 16,000 children, 400 teachers and 80 schools, in six of the mayor cities of Colombia. At the same time, the program have conducted research and implemented new practices to document the changes introduced and generated in the schools, teachers, children, and the whole educational system.

For example, over the last year, the program has directed considerable efforts to document and research on a topic that has been mentioned by most of the actors involved in the implementation of it. Teachers and children often mention that one of the first gains they get from the work in the program is the betterment in their peers relationships and communication. In the Colombian educational system, teachers are faced frequently with aggression and violence problems inside their classroom that stops them from their guiding role and directs them to crisis interventions, most of the time leaving scientific knowledge and competences out of the picture.

In response to this reality, Pequeños Científicos has shown to multiple Colombian teachers and students that some educational practices could improve the coexistence inside the classroom, while at the same time ensuring the conditions for scientific knowledge and competencies development. Backed up by the Colombian Education Ministry proposal of basic standards for the areas of science [7], mathematics and language [8] and citizenship [9], the program has showed that science teachers could participate in the children socio-emotional and communicative formation without leaving aside the scientific domain.

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By the promulgation of science [7], mathematics and language [8] and citizenship [9] standards, the Colombian Education Ministry have stated clear and public criteria that allow the public to understand what children should learn, as well as to establish a reference point of what they should be able to know, and know how to do in the different areas. Particularly, the citizenship standards present three different domains where children should develop competencies (peaceful coexistence, democratic responsibility and participation, and plurality, identity and value of the difference), as well as multiple advise for teachers from all of the academic areas to participate in the civic, socio-emotional and communicative formation of their students. In addition, science standards back up the citizenship standards, and the involvement of science classes in the civic formation of students by presenting a

**Program Description**

Pequeños Científicos as a scientific literacy and competencies development program focuses on giving children the experience of a completely scientific inquiry process. In a typical Pequeños Científicos session, children get engage in hands on - minds on activities that let them observe, predict, make hypothesis, measure, conclude and communicate to each other their findings. Children are constantly working cooperatively with their peers so they can be exposed to different opinions, listen to them, debate and argument them, to finally arrive at a group construction. This construction will account for the studying phenomena, at least until the group meeting is held, where all children present their findings and conclusions, and the group as a whole tries to reach to one o two general conclusions.

In the typical session, teachers play a guiding role, trying to question children conclusions, driven them to consensus seeking and progressively letting them decide on their groups inner functioning and knowledge construction. Teachers inside programs like Pequeños Científicos, by definition act as a scientific role model, and as a guide, that accompanies the development of the children. Teachers and children work reflects on the original Vygotsky (1982) ideas of zone of proximal development, acting as scaffolding for their peers’ development.

In addition, teachers are the means by which the program get involve with the children and institutions. Teachers interested in the program participate in a year formation program that presents them with the tools and experiences to implement effectively the pedagogical strategies in their classroom. This formation, most of the time led teachers to explicit and change their teaching and learning conceptions, while conduce them to consider a more active role of students in their own learning. Teachers directly experiment what the core principles of the program are, while they start to implement them in their own classes. Mid term workshops and classroom observations, conducted by the program staff and experienced teachers, give the new participants feedback and reflections on their practice.

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Relying in approaches like teachers training, scientific accompaniment, curriculum development and strategic planning and, assessment the Universidad de los Andes school of Engineering program Pequeños Científicos, has located graduate and undergraduate resources in the elementary school, aiming to improve the children scientific literacy. At the same time, due to the means the program has chosen to work in the classroom, children and teachers have developed science and technological understanding, as well as socio-emotional and communicative competencies.

This paper, outline some of the classroom strategies used by the Pequeños Científicos program, while shows the process and results of a research aimed at the construction of a citizens competencies assessment tool for the science classroom.

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group of competences related with the relationship between science, technology and society.

In line with this, most of the Pequeños Científicos classroom practices recognize and seek to promote the integration of scientific and citizenship competencies in the science classroom. For example, the cooperative groups that children organize inside the science class allow them to share and communicate with a group of three or four peers, while discussing scientific related topics. While children work, they face and solve every day relational problems and get acquaintance whit peers who they are not close friends. Authors like Johnson, Johnson & Smith [10] and Slavin & Cooper [11] who document the impact of cooperative work in the socio-emotional development of the children, as well as on friendship establishment among boys and girls of different backgrounds sharing in the same class have extensively supported these benefits of the cooperative work. However, these groups, as well as those established in the Pequeños Científicos classroom are not traditional in their conformation and roles. They must have special features like those suggested by Johnson, Johnson & Smith [10]: positive interdependence or the sense of intimacy and opportunity to contribute to achievement of the goals by all the group members; the establishment of a long relationship where children get acquaintance with their peers and the assignation of specific roles and responsibilities for a given task. All of these features are present in the cooperative groups established in the Pequeños Científicos classroom, and seek to integrate children around scientific knowledge, while at the same time allow them to relate peacefully to each other. Also, some other insights from research are integrated in these cooperative groups.

For example, the recommendations issued by Daza, & Rodriguez [12] that state the particular relationships between cooperative work and science classrooms are also present in Pequeños Científicos groups. These authors suggest that the establishment of cooperative groups in the science classroom allow children to interact in a face to face relationship, while they face the error of themselves and their peers, and by this mean they become more competent in dealing whit someone else opinions and supporting evidence. By these, Daza, & Rodriguez propose that when children ask their classmates for evidence on their scientific opinions, they are able to construct knowledge and develop competencies for their active participation in society. In the same line, Matthews, Kilbey, Doneghan & Harrison [13] and Matthews [14] present a work framed in the emotional literacy stream, developed by Steiner & Perry[15], that prove to relate the science classroom work with the development of skills and competences for recognize, understand and express emotions in a constructively manner, while empathizing with close and farther peers. Particularly, Matthews et al [13] and Matthews [14] present a project called Improving Science and Emotional Development (ISED) where they seek to establish a learning atmosphere inside the science classroom, letting children working in mixed genders cooperative groups around a scientific topic, measure and report their peer’s interventions in the work, and the reactions of their group members. At the end of the work session, children get together, share and analyze their observations and results and the influence of these on the group performance. This simple practice has shown to be powerful in the development of children skills for dealing with conflicts, negotiation, gender integration and decision-making, while at the same time allow them to fully participate in the construction and understanding of scientific knowledge and to develop a group of positive attitudes towards science.

Pequeños Científicos cooperative group’s organization seeks to reflect on all the recommendations issued by these authors, and give children the chance to fully participate in the active construction of knowledge, while at the same time they relate to each other and face conflicts and situations raised by the interaction. This opportunity, given by the conformation, distinctively features of the cooperative groups and, the work around scientific topics allow the integration of the scientific and citizenship domain in the classroom, and is one of the dimensions the Pequeños Científicos program has chosen to develop socio-emotional and communicative competencies in the science classroom.

The second feature by which the program seeks to integrate citizenship, socio-emotional and communicative competencies in the science classroom is the configuration of a learning atmosphere that allows teachers and children to communicate their opinions and conclusions on a given topic. Behind this learning atmosphere lies the idea of the error as an opportunity for learning, giving children the chance to listen to their peers and teacher ideas while asking in a caring manner for supporting ideas and evidence. Obviously, children usually have not developed the competencies needed for using the error as a mean for learning, and here is where the teacher should guide them and structure the classroom participation and dynamics so the children will gradually overcome the traditional conceptions around the error and fully participate in the Pequeños Científicos sessions. Also the teacher must play as a role model for children and model the way is expected they manage their error and their peers’.

This particular topic is one of the most difficult issues teachers must face in their training workshops, as they are also used to correct and prevent children from making mistakes and communicate their errors. However, this aspect is also one of the most powerful tool teachers can count on to develop scientific and citizenship competencies in their children. The work of Nix, Frasser & Ledbetter [16] and Haukoos & Penick [17] shows how the construction of a learning atmosphere, that includes elements related with a constructively vision of the error, the opportunity to debate and argument ideas, and communication features as paraphrasing, active listening, and assertively communication have an impact on both children understanding of science and scientific and citizenship competencies development.

Finally, a third dimension by which children in the Pequeños Científicos program face and developed competencies related with the scientific and citizenship domain, is the relationship between the scientific knowledge their developing and their lives and their communities’. Although, this is one of the less
developed dimensions in the program, there has been some work aimed at the construction an adaptation of materials for the critical analysis of the impact of scientific and technological knowledge on the children private and communitarian lives. Particularly, reflecting on the work of Klostoe [18] and Aikenhead [19] the program has seek to introduce some spaces and activities for children to observe, predict, analyze and experiment their daily environments and the links between these and the scientific knowledge their working on. Specially, the work on topics as habitats, structures and, me and the others, allows these relationships to be established. Further work and research inside the program is needed on this topic to truly allow children and teachers to explore the relationships between science, technology and society.

On the other hand, some features of these integration between the development of scientific and citizenship or socio-emotional competencies, have been included in the structure of a new assessment tool, that based on the characterization posed by the National Science Foundation (Frechtling,, [20]) seeks to gather information on the process and results of the program. This new assessment tool, also seeks to inform to all the actors involved in the implementations of the program what are the goal stated for the integration of citizenship and scientific competencies development inside the Pequeños Científicos classroom.

THE CONSTRUCTION OF AN ASSESSMENT TOOL

We started the construction and development of this tool with the following research questions:

1) What are the performances of understanding related with citizenship competencies that children, working in the Pequeños Científicos program, are able to demonstrate.

2) How can be described those performances.

We started to conduct focal groups and performance experiences whith a group of 20 boys and 20 girls from different classes working with the program in the city of Bogotá. There we asked children to conduct a science experience, while trained observers recorded their performance and later interviewed them focusing in the way they handled their relationships inside the group, the cooperative work, the error and the relationships between the science topic and their lives and communities.

Once all the field work was finished, results were analyzed and open coded, trying to establish categories of analysis that reflect the performance and answers stated by the children as evidence of what really children experience of the integration of citizenship, socio-emotional and communicative competencies in their science classroom.

Table 1, shows this initial structure of categories emerged from children responses and performance.

Once these results were categorized and analyzed, we started the construction of a pen and pencil test that will allow us to estimate children performance on citizenship competencies inside their science classroom. In addition, because of the observations realized we decided to create also a learning atmosphere assessment tool that will let us know what were the conditions present in each children classroom, how teachers established these conditions and, how these conditions relate with the development and performance of children in the citizenship competencies domain.

As a result, two instruments were designed and created:

- one focuses on the performance of understanding of citizenship competencies that children working in the Pequeños Científicos program exhibit
- A second dealing with the perception of children and teachers of the learning atmosphere conditions inside the science classroom.

It was hypothesized that those children and classes that showed a better perception of their learning atmosphere will indeed show a better performance in their citizenship competencies inside the science classroom.

Finally, both instruments reflect the same dimensions, extracted from the data categorized and analyzed. In the following table 2, the final factorial structure is shown.
The integration of scientific and citizenship competencies in the science classroom is necessary for educational projects working in the K-6 classroom. The scientific literacy goals stated for education, point at the constructively participation of individuals in the social decisions relating with scientific knowledge. Now days, almost any social decision relate with scientific and technological domain knowledge, and citizens need to understand other people opinions, their emotions and to evaluate from a critical point of view their reasons for supporting a given alternative. Children need to be taught on the scientific inquiry process, in how scientific knowledge is socially constructed, and in its relations with technology and society. The Pequeños Científicos program recognizes these goals, and includes some educational practices that allow children to relate to each other and construct scientific knowledge. By the use of cooperative work, the configuration of an error and opinion respectful learning atmosphere, and the development of caring relationships between group members and, teachers and children, the program seeks to contribute to the citizenship formation of children, without leaving aside their scientific and technological development. In addition, by the construction and development of new assessment tools that deal whit this features, the Pequeños Científicos program seeks to gather information for the follow up the implementation of the program, while at the same time obtain some results from the process and results employed in the science classrooms. At the same time, the construction and implementation of this new assessment tool, seeks to inform to all the actors involved in the implementations of the program what are the goal stated for the integration of citizenship and scientific competencies development inside the Pequeños Científicos classroom.

Once we defined this final factorial structure, we started to create questions for both the learning atmosphere questionnaire, and the citizenship competencies in the science classroom questionnaire. These questions reflect what actually children responses and performance were in the observations and focal groups done, and wanted to grasp some of the actual performance children exhibit in their science classroom.

By now, the instruments designed are going through a pilot study phase, where empirical validation is sought. Results from this phase are not ready yet, but preliminary results show positive and significative correlations between some of the learning atmosphere questions and the citizenship competencies questions. In addition, some differences between classes that exhibit different levels of learning atmosphere are reproduced in differences in the citizenship competencies performed by the children. Further research and validation procedures are needed to establish the instruments as a valid mean to document the program impact on children citizenship competencies, however the initial steps are already taken, and preliminary results show a positive integration of socio-emotional, communicative, citizenship and scientific competencies en in Pequeños Científicos science classroom.

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TABLE 2
FACTORIAL STRUCTURE FOR THE ASSESSMENT TOOLS DESIGNED

<table>
<thead>
<tr>
<th>Factors</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooperative Work</td>
<td>Questions that allow us to identify if the science classroom uses elements like cooperative roles, positive interdependence, and cooperative work among their members. Also, questions reflecting the performance of children in these elements.</td>
</tr>
<tr>
<td>Opinion and democratic</td>
<td>Questions that allow us to identify is the learning atmosphere promotes the opinion among children. Also, the degree in which actually opinions are considered as valid by group members, how teacher’s value children opinions, and how children participate in consensus making inside the science classroom.</td>
</tr>
<tr>
<td>Error</td>
<td>Questions that allow us to identify how error is managed inside the science classroom. What is the reaction of peers and teachers once children make a mistake, how this reaction affects children participation in the class, and how children and teachers use alternatives to react to others error.</td>
</tr>
<tr>
<td>Teacher – child relationships</td>
<td>Questions that allow us to identify the quality of relationships between children and, teachers and children. How children perceive their teacher, how children perceive others children roles inside the science classroom.</td>
</tr>
<tr>
<td>Presence and dealing with the conflict.</td>
<td>Questions that allow us to identify the ability children have to deal with the conflicts among group members, to create new alternatives and to listen to their peers and teacher to deal with a given conflict.</td>
</tr>
</tbody>
</table>

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REFERENCES


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