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Waking up scientific vocations

Eduardo Dopico^{a*}, Department of Education Sciences, Faculty of Education, University of Oviedo, Asturias, 33001, Spain.

Cristina Armstrong^b, Cawthron Institute, Nelson, 7010, New Zealand.

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Abstract

Schools must promote scientific vocations designing teaching-learning strategies that involve teachers, pupils, scientists and the students' families. Keen on this idea we have developed a didactic participative design to promote science learning in students of primary and secondary schools. With the collaboration of teachers from three primary schools in Nelson (New Zealand) and three high schools (secondary education) in Asturias (Spain), educational sessions were organized where scientists posed research challenges to 323 students. While they were learning key concepts about science they were instructed about basic scientific methodologies with the aim that they could carry out some research by themselves, both individually and in groups. The transfer of knowledge acquired during the sessions transcended the school environment because students shared their research with their families. Scientific vocation can be worked up in the educational environment by changing the teaching methodology and introducing current and relevant scientific topics. Teachers should count on the active participation of scientists for this. When the students of these educational levels are involved in real research their scientific vocation is stimulated, as is the transfer of scientific knowledge to the families.

Keywords: Science education, project-based learning, cooperative learning, teaching methods.

* ADDRESS FOR CORRESPONDENCE: **Eduardo Dopico**, Department of Education Sciences, Faculty of Education, University of Oviedo, Asturias, 33001, Spain.

E-mail address: dopicoeduardo@uniovi.es / Tel.: +0-528-845-74-74

1. Introduction

The scientific level of a country begins at school. From the early educational stages, science education has to run transversely through the curriculum's intentions to develop the natural curiosity and creativity of young students (Fensham, 2008). A suitable scientific education contributes to training citizens interested in their living environment, develops their critical and creative thinking and helps to democratize decision-making in matters that affect the future of society (Oliver, 2006). The teachers' role to stimulate scientific curiosity and encourage creativity in children is crucial to develop the scientific culture of a country. Hence the importance of designing good science education curricula (Eshach, 2006). In the earliest educational stages successful science literacy will encourage the scientific vocations of the students, at least in the ideas expressed by children in kindergarten and primary education (Osborne & Freyberg, 1985; Hartung, Porfeli & Vondracek, 2005; Brown, Ortiz-Nuñez & Taylor, 2011). Further along the educational path, the organizational structures dominated by men and the misogynous attitudes that prevail in our society limit the scientific aspirations of working-class girls especially (Archer et al., 2013), and gender appears to be a key factor in the vocational choices: Women choose medical, teaching or nursing careers by preference; men choose fields like engineering or computer sciences (Buccheri, Gürber & Brühwiler, 2011). Economic differences, educational level of parents, gender and also outdated curriculum proposals are the most notable difficulties observed in the teaching of science in schools (European Commission, 2011). On a strictly pedagogic level it is still detected that students have problems in understanding the role that science has in society and in their lives (Allchin, 2011). Students complain about the unnecessary complexity that teachers insist on introducing in the teaching of sciences (Lyons, 2006), the lack of connectivity between the curriculum and the content of the subjects (Convert, 2005) and the abuse of expositive sessions typical of a transmissive pedagogy. Some researchers have suggested that one of the reasons for the science curriculum not having the expected success is that teachers have an inadequate notion of what science is (Posnanski, 2010). If there are dissonances in the aims of education or inconsistencies in the approaches of the teaching of science among teachers the transfer of knowledge in classrooms will be weak (Dayle, 2015). For a long time, class sessions of science, technology, engineering and mathematics (STEM) subjects have centered almost exclusively on the construction of knowledge for itself, with sciences appearing as a set of finished knowledge, decontextualized from the process by which it was produced (Godoy, Segrra, & Di Mauro, 2014). The curricular pressure of a teaching appraised by trimesters confines the learning to a very inflexible programming and makes it hard for teachers to link the science contents with scientific knowledge and prior learning experiences of their students (Martín del Pozo, Porlán & Rivero, 2011). 21st century science does not support such rigidity, and teachers are demanding changes. The creative thinking, problem solving, motivation and continuity of learning which characterize the teaching-learning of science nowadays require to constantly adapt the curricula. In the times of Dewey (1916), to handle the scientific method was more important than to acquire scientific knowledge. Nowadays we need students to have a general knowledge of the subjects, to develop the capacity to think critically, to be competent at solving problems in a creative and collaborative way, to increase their communication skills, to adequately use ICT and, obviously, to use the scientific method. To do that, teachers have to teach effectively, designing good learning experiences in science (Jeanpierre, Oberhauser & Freeman, 2005; Rosenblatt, 2011), working with others inside and outside the school context and persisting in their own continuing training. Initiatives on these three key points have been developed by university science research teams to bring practical science to schools. We set out to continue this dynamic by testing an innovative teaching-learning experience in science simultaneously accompanied by a change in teaching methodology. We designed and carried out a project to implement participatory scientific activities based on project-based learning (PBL) and cooperative learning (CL) to promote scientific learning in students of primary and secondary schools in Nelson (New Zealand) and Asturias (Spain). Project-based learning is a methodology that enables students to acquire knowledge and key skills by developing projects that respond to real-life problems (Hung, Jonassen & Liu, 2008). Acting complementarily with cooperative learning (Mehta & Kulshrestha, 2014), pupils turn into protagonists

of their own learning guided by teachers who promote groups of effective collaboration in the classroom (Webb et al., 2009). These groups work autonomously, under their own control/of their own volition, since they are in charge of planning, structuring and executing the tasks necessary to solve the question raised by the teacher. The work of teachers is then to guide and support the students throughout the process, ensuring the harmonization of the groups (Pons, Prieto, Lomeli, Bermejón & Bulut, 2014). Our idea of bringing science to schools pretended to encourage scientific vocations by designing teaching-learning strategies that involved the teachers, the scientists and the students' families.

2. Material and Methods

With prior demand and collaboration from teachers from three Elementary schools (primary education) in Nelson (New Zealand): Murchison School, Waimea Intermediate and Clifton Terrace; and three high schools (secondary education) in Asturias (Spain), CPEB Cabrales, IES Carmen y Severo Ochoa, Luarca and IES Tineo, science educational sessions were organized between May 11 and November 30, 2015, where scientists, in collaboration with teachers, posed research challenges to students. The topics were ecotoxicology (Nelson) and biological invasions (Asturias) (Table 1). While they were learning about science, they were instructed about scientific methodologies so they could carry out a research on their own, both individually and in groups.

Table 1. Study sample

Site	Primary School	Secondary School	Problem	Students	Average age
Nelson, New Zealand	Murchison School		Ecotoxicology	25	11,5
	Waimea Intermediate			120	12
	Clifton Terrace			25	7,8
Asturias, Spain		CPEB Cabrales	Biological invasions	28	14,5
		IES Carmen y Severo Ochoa, Luarca		45	16,7
		IES Tineo		80	16,8
Total	3	3		323	13,21

The chosen teaching method was project-based learning that implied the learning of science through solving problems of ecotoxicity (Nelson) and biological invasions (Asturias). With this constructivist approach, the problem is what defines the learning (Pepper, 2009). Students analyze the problem they face and the context in which it takes place to understand it and find ways to either solve it or intervene on it (Etherington, 2011). Organized in cooperative groups, students work together to maximize their own learning and that of others (Johnson & Johnson, 2014).

During that period we also held specific meetings only with teachers to think in common about the teaching of sciences today because teachers not only need to dominate their subjects, they also need be aware of the strengths and weaknesses of their teaching practice (Bakx, Koopman, de Kruijf & den Brok, 2015). We met with science teachers in primary education at Dovedale School (Nelson, New Zealand) and with science teachers in secondary education attending a Permanent Training Course (Asturias, Spain), with the aim of drawing the concerns and priorities faced by teachers to improve the scientific literacy of students. The data collection method was based on the dynamics of meetings (Figure 1).

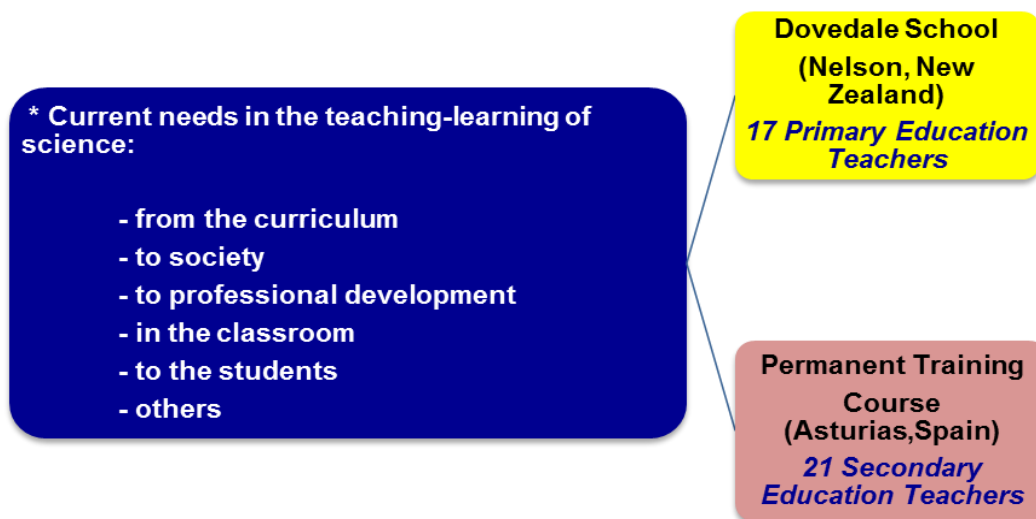


Figure 1. Teachers' perceptions on teaching science

3. Results

Two scientific activities were designed by the Science Education program at Cawthron Institute and the Department of Education Sciences at the University of Oviedo for the 6 schools in the sample, and the results shown in Table 2 were collected with the collaboration of teachers and students.

Table 2. Schools, activities and main results

School	Topic	Activity	Main results
Murchison School	'Up the Pipe' Ecotoxicology	Comment with students the increase in chemicals found in household products of everyday use and their impact on the environment.	✓ The project-based learning task generates enthusiasm among students. Everyone wants to participate and contribute with ideas.
Waimea Intermediate		Each cooperative group exposes how the knowledge of the problem is generated and provides easy solutions.	✓ Cooperative learning increases the competencies for teamwork.
Clifton Terrace		Develop an exercise on the chemistry of soap, contributing basic knowledge about hydrophobic and hydrophilic properties while making soap in the classroom	✓ The teachers present in all sessions outlined new designs for future activities.
CPEB Cabrales	Biological invasions	Introduce with pictures and cartoons the concept of biological invasions, with some examples from the region.	✓ Students checked personally how the scientific procedures work while they acquire basic concepts.
IES Carmen y Severo		Explain why invasive species could be a serious ecological problem. Discuss the paradox that species native to (and protected in) a region can be dangerous invaders in another.	✓ Practice precedes theory, facilitating meaningful learning.
		Bring some individuals of invasive species common in the region. Distribute one species per cooperative group and a brochure	✓ The transfer of knowledge acquired during the sessions transcended the school environment.
			✓ The 323 students of the two levels (primary and secondary) that participated in these sessions involved their families in the

<p>Ochoa, Luarca</p> <p>IES Tineo</p>	<p>describing the species and its potential for ecological degradation.</p> <p>Finally, students are organized into teams to create environmental monitoring patrols.</p>	<p>research challenges, enlarging the educational frame to the community.</p> <p>✓ The results obtained by students were presented in public exhibits in the schools, open to the general public.</p>
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We collected the concerns and needs that were expressed openly in relation to science education in the meetings with teachers. In a qualitative analysis of those data we found that, except for small aspects of a strictly local character, both groups of teachers expressed similar opinions about the needs that teaching and learning science requires at present (Figure 2).

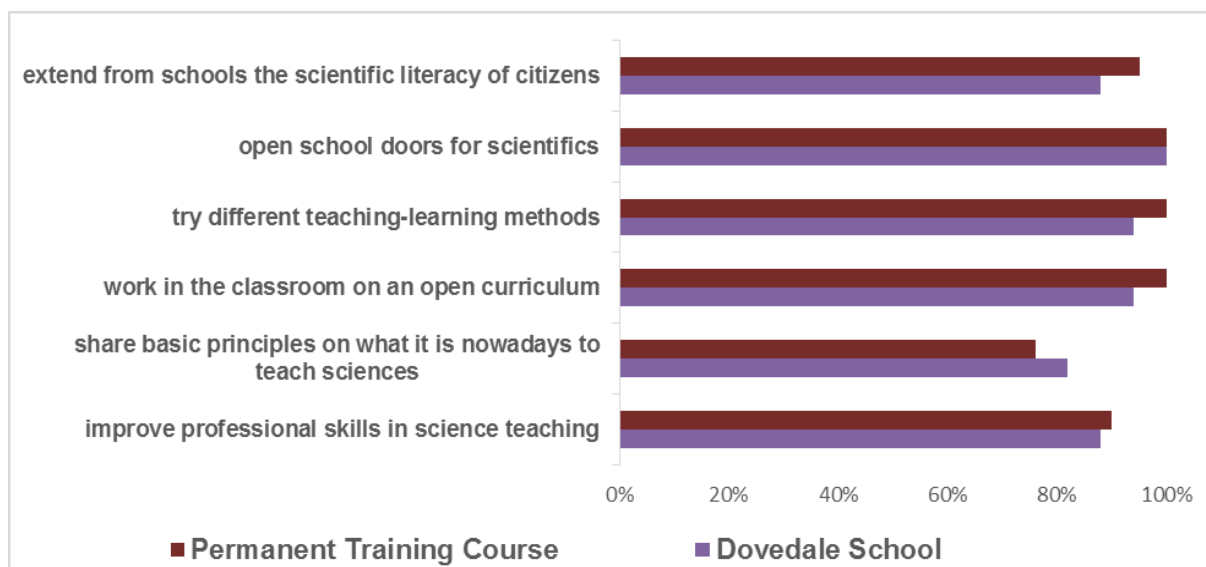


Figure 2. Improvements needed in the teaching of science, according to the interviewed teachers.

Both groups agree that there is a need to increase the scientific knowledge of the citizenship (91,5%), to improve the operability of scientific inquiry procedures with new teaching methods (97%), to count with collaboration from scientists in class sessions (100%), to work on a flexible and adaptable curriculum (97%) and to increase own professional competences to meet the challenges that science education raises at the present time (89%).

4. Conclusions and Discussion

We live in a time of growing demand for scientific knowledge by the population (Innerarity, 2013) and the school system cannot remain indifferent to this. School hours in sciences need to be improved by opening the curriculum to cover the scientific advances that are constantly produced. Teachers continue to express the need for improvement in their professional competences to adequately teach science. It seems that projects already established to this end do not achieve the expected outcomes. Despite examples such as the *Learning in Science Project* developed by the University of Waikato in New Zealand on constructivist pillars, trying to help science teachers to improve their teaching skills in the classroom (Bell, Kirwood & Pearson, 1990), the *Primary Connections*, leaning on the curriculum, based on teacher's competences with the purpose of improving outcomes in the teaching and learning of science (Hackling, Peers & Prain, 2007) and, more recently, the *Learning and Teaching Primary*

Science project encouraging teachers to introduce research and practice evidence in science classrooms (Cutter-Mackenzie & Logan, 2013), teachers are still unsure of their capacities to teach science in the classroom, although they show interest in improving and they test innovative ways in bringing inquiry-based procedures to their pupils. As we have seen in this pedagogical experience, teachers are deeply committed to the development of the scientific potential of their students. Teachers of both primary and secondary schools involved in these scientific sessions shared the idea that scientific vocation can be worked and enhanced in the educational environment by changing the teaching methodology and introducing current scientific issues relevant to the life experiences of the students and their environment (Carrier, Tugurian & Thomson, 2013). To make it effective, teachers must secure active participation from scientists. We have seen how involvement in actual scientific research encourages the scientific vocation of students in the sample and, at the same time, how the transfer of scientific knowledge built in the classroom moved to the families. Projects similar to the one we present are performed around the world; the effectiveness of this approach that pays particular attention to research-based teaching has been verified by hundreds of empirical studies (Baker, 2015). It improves overall scientific literacy, promotes the aptitude to learn and the motivation to keep learning (Harlen & Qualter, 2014). It means teaching science by doing science, providing basic knowledge to start a process of inquiry-based learning run by the students themselves and monitored by teachers to continuously verify what students are learning (Loughland & Kilpatrick, 2015). Our work is limited by the number of schools presented. We need to extend the school sample to achieve that goal.

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