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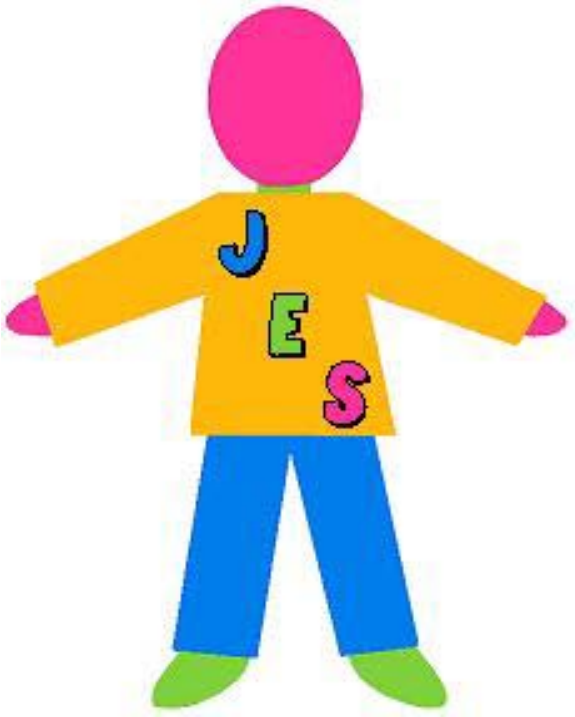

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Pre-school science education in Portugal: teacher education and innovative practices

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Assuming that science education in the early years is the stepping stone for the development of scientific and technological literacy, a teacher training programme was developed with six kindergarten teachers in Portugal. Its aim was to promote the (re)construction of their subject content and pedagogical knowledge leading to innovative practices, based on the characterisation of their profile, shortcomings and practices.

Learning through practice was considered the most effective means to promote change in kindergarten teachers' curricular approaches to science, hence the development of practical activities focusing on children's understanding and requiring their scientific knowledge and enquiry processes. These include a teacher's guide (presenting its objectives, concepts and teaching, learning and assessment strategies), a theoretical framework (presenting the concepts, known misconceptions and research references) and also the necessary didactic resources.

This article details the results of the developed teacher training programme.

Keywords: science education; pre-school; teacher education

1.0 Theoretical framework

Today, scientific and technological literacy is assumed by the research community to be a vital component of the early years teaching curriculum (Osborne & Dillon, 2008). Science and technology should take place in the early years classroom, in a child-centred approach and in a socio-constructivist environment, which will allow children to progress from a description to an explanation of the natural phenomena they observe in their daily lives. In turn, children will also become more competent in constructing shared and 'big' ideas, evolving from personal and 'small' ones (Harlen & Qualter, 2004).

It is no longer debatable that science education does undoubtedly contribute to scientific literacy. A vast number of researchers (such as Harlen, 2006; Eshach, 2006; Van Hook & Husiak-Clark, 2008; Hadzigeorgiou *et al*, 2009; Keogh & Naylor, 1999; Charpack, 1996; Martins *et al*, 2007; Martins *et al*, 2009), have presented the reasons for early science teaching, which should be regarded as a right for every student (Fumagalli, 1998), along with the right for education (UNESCO & ICSU, 1999).

The challenges facing 21st Century society are more efficiently met when the science curriculum is developed within a science-technology-society focus, as far as scientific literacy is concerned (Acevedo-Diaz *et al*, 2003; Aikenhead, 2002; Membiela, 2001). School science is more relevant and appealing to students when it is taught embedded in social contexts that are meaningful to them, with a displaced focus from the teaching of concepts. Children should be able to construct an authentic image about science and technology and about the way scientists work. They should form an elementary idea about the role that science and technology play in their lives and in the evolution of humanity and its relation to the planet in which we all live. School science should contribute to preparing future citizens to critically interact with their world, with its increasing complexity, considering social and ethical values when deciding and acting upon its problems and demands. It is vital that, at an early age, students should develop positive attitudes towards science and science teaching, where the science-technology-society strand of the curriculum will help promote students' motivation both for science and school science (Caamaño & Martins, 2005).

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Recent studies on scientific literacy (PISA, 2006; EUROSTAT, 2003) show that Portuguese students ranked poorly compared to most European countries, with results close to those of Italy, Israel and Greece. These are results below OECD average, showing an impact of socio-economic and cultural background above OECD average (Pinto-Ferreira *et al*, 2007). These are facts that reinforce the need for new and innovative ways to teach science, beginning in the early years.

2.0 Pre-school education in Portugal

In Portugal, kindergarten, or pre-school, is non-compulsory, aimed at children between three and six years old. It is provided both in private and public (state) schools, with the latter provision having been established from 1974.

In 1997, the Ministry of Education published the *Curricular Guidelines for Pre-School Education*, presented as guidelines for kindergarten teachers and unlike a curriculum. Its goals are to raise the social value of pre-school education, to improve and rationalise teaching practices nationwide and to promote articulation with elementary schools. These guidelines present three main content areas, which are regarded as fields of knowledge, and include different scopes of learning, considering attitudes and know-how as well as knowledge itself.
The three content areas are:

- *Personal and Social Development*
- *Expression and Communication* (including the following domains: physical, drama, plastic and musical expression; oral expression and writing approach and mathematic expression)
- *Knowledge of the World* (regarded as a first approach to science, experimental and social sciences and to scientific thinking).

3.0 Changes in science education

Facing the current situation, considering science education at the kindergarten level and, in particular, science education in the Portuguese context, government authorities have shown an interest in investing in science education in the early years. In the more recent years, some steps have been taken to contribute to the improvement of the Portuguese early years provision.

The *Program of Primary School Teacher's Education in Experimental Science Teaching* has been developed for four years in Portugal and is seeing an increasing number of elementary teachers enrolling each year (from 986 teachers in 2006/2007, to 2940 in 2008/2009). It is sanctioned and financed by the Ministry of Education, with a workload of 126 hours per year, and consists of a variety of types of sessions aimed at teachers with qualifications at Master's or PhD level. Teachers interested in attending a second year have a whole set of new content available. All the publications relating to this programme are presented in the form of thematic booklets available on the Internet at **www.dgidc.min-edu.pt/experimentais/Paginas/Recursos_Didacticos.aspx**

In January 2009, the Ministry of Education published a booklet entitled *Despertar para a Ciência – Actividades dos 3 aos 6* (*Wake up to science – activities for 3-6 year-olds*), which provides teachers with a theoretical framework supporting science education in kindergarten, as well as 20 practical activities and references to support innovative practices in science. This booklet is available online at **//sitio.dgidc.min-edu.pt/recursos/Lists/Repositrio%20Recursos2/Attachments/805/pre_ciencias_1.pdf** and was delivered to the administrative services of every school in the country. At the same time, a nationwide training programme was implemented, intended to allow kindergarten teachers to learn, reflect and discuss the actual guidelines regarding science teaching in kindergarten, as well as experiment with and access the practical activities presented in the booklet.

In 2007, the same Ministry issued *Regulation nº17/DSDC/DEPEB/2007,* which presented kindergarten teachers with guidelines to support the construction of their classes' curriculum, clearly emphasising science education as an important part of this.

4.0 Promoting change

As well as the measures taken to invest in school science, changes in the education system, to be effective, should take into account the complementary influence of the three main axes of education in general, and of science education in kindergarten in particular: the *kindergarten teacher* (and his/her underlying education process); the *curriculum;* and the *resources* available to implement such a curriculum (Eurydice, 2006; Osborne & Dillon, 2008). It is therefore understood that this is an approach that should be considered in a multi-dimensional way, leading the authors to choose to work co-operatively, benefiting from the expertise drawn from each other's investigations. The teacher training programme, as presented, was developed by two teams of researchers, each researching different aspects related to science education in kindergarten: teacher training, and the science curriculum.

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5.0 Project presentations

Project A is entitled *Kindergarten Teacher Continuous Education – Contributions for the performance of experimental activities with kindergartners* and its aim is to design a teacher training programme that promotes the (re)construction of subject content and pedagogical knowledge, leading to innovative practices in science education in kindergarten. The developed programme was to be based on the characterisation of the kindergarten teachers' profiles, shortcomings and practices, in order to establish its objectives, contents, strategies and assessment.
To accomplish that purpose, a questionnaire was handed to all the teachers in public and private kindergartens in the Bragança district in northern Portugal in May 2008. Its main purpose was to collect essential data in order to better understand kindergarten teachers' characteristics and expectations, and so to establish and sustain the content of the teacher training programme to be developed. It was structured in three main sections:

- kindergarten teachers' personal characterisation;
- their professional experience and development; and
- aspects related to their practices, namely those regarding content from *Knowledge of the World,* (i.e. science teaching).

Achieving a response rate of 91.5%, it was possible to take into consideration 194 (out of 213) answers. Analysis of the questionnaires allows us to conclude that, compared to teachers in private kindergarten schools, teachers in public schools are, on average, older (45 years old), have longer periods of practice after their academic degrees (over 15 years) and a lower investment in continuing professional development, with 81 teachers out of those sampled having attended no teacher training programme at all and just 21 attending only one. The main reason given by the teachers to justify such a low attendance is the shortage of in-service teacher training programmes available, although they all emphasise the relevance of and need for such programmes to support their professional growth. Those teachers who did attend teacher training programmes show a higher score related to their didactical practices, showing a higher frequency of science-related activities.

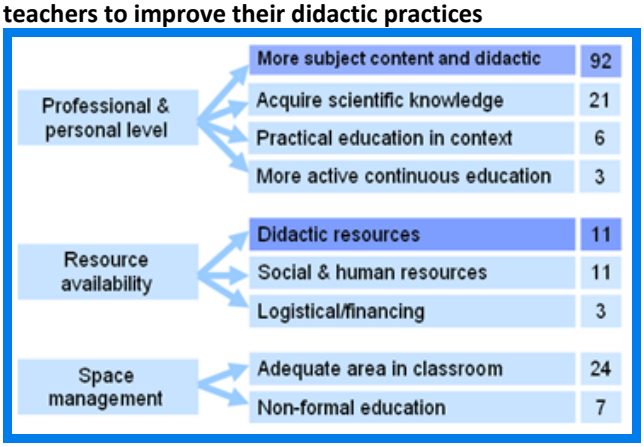
The majority of teachers stated that science should play an important role in their school curriculum, but were unable to elaborate on its aims, purposes and the possible strategies to implement it. The difficulties in conducting scientific activities outlined by kindergarten teachers are presented in Table 1 below, with most being attributed to a poor initial and in-service development.

Table 1 – Difficulties felt by kindergarten teachers in conducting scientific-related activities

Scale	Response ratio %					
1=very high, 2=high, 3=medium, 4=low, 5=non-existent	**1**	**2**	**3**	**4**	**5**	**N/A**
Scientific knowledge	2	7	66	17	2	7
Planning	1	9	56	25	4	6
Activity development with children	3	11	51	23	6	7
Content selection	1	11	51	25	5	7
Content adaptation to children's age	4	14	42	28	5	7
Resource acquisition	8	21	46	16	3	6
Connections with other content areas	2	13	41	28	6	9
Group management	2	18	37	26	10	8

Considering the responses given, the teachers suggested measures to improve their own didactic practices, as presented in Table 2.

Table 2 – Suggested measures by Kindergarten teachers to improve their didactic practices



Project B is entitled *Scientific Literacy in Kindergarten – a curriculum proposal* and its aim is to develop a kindergarten science curriculum with a science-technology-society (STS) focus, while establishing adequate science content, process skills and scientific attitudes. It encompasses also the development of a number of practical activities, presenting and detailing the concepts involved, as well as including the necessary educational resources (consisting of a teacher's guide and all the required materials to develop each practical activity).

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The empirical validation process of these teaching strategies is to be developed by a number of kindergarten teachers who participate in a specific in-service training programme. Analysis of this process will lead to the definition of a science curriculum for kindergarten, presenting *what* to teach (a set of concepts), *why* teach science (the science process skills and scientific attitudes) and *how* to teach science to pre-schoolers (a set of teaching strategies). This is a process developed along the lines of Hodson (1996, 1998) and the American Association for the Advancement of Science, as presented in *Benchmarks for Science Literacy* (AAAS, 1993).

The overall purpose of this project is to present a science curriculum based on the assumption that kindergarten is a setting in which young children have to take an active part in learning situations that support both the investigative (skills and attitudes) and knowledge-based aspects (concepts) of science education.

From an initial analysis of the *Curricular Guidelines for Pre-School Education* (Ministério da Educação, 1997), some limitations in the document emerged. As a 14 year-old document, it shows itself as very generalistic, where the STS and Education for Sustainable Development (ESD) perspectives are omitted and with inexplicit content presentation and a lack of relevant concepts. It is inexplicit in its competence development presentation (regarding science knowledge, skills, values and attitudes), failing to present clear teaching and learning strategies (regarding types of activities, the framework, the resources…). Discussion about the elementary school curriculum is also absent, leaving kindergarten teachers unsupported in planning their own. These are some of the limitations of the Portuguese curricular document in a context in which, over the last decade, we have witnessed an increased awareness of the role of early science teaching as a consequence of the progressive preponderance of science and technology in modern-day society.

Data were gathered from the analysis of the Portuguese curricular guidelines, as well as of the curricula of the USA and other European countries. These, supported by international investigations in this domain (Saracho & Spodek, 2008; Van Hook & Husiak-Clark, 2008; Havu-Nuutinen, 2005; Hadzigeorgiou *et al,* 2009; Johnston, 1998), led to the development of ten teaching strategies. These practical activities were firstly validated in a real-life context by kindergarten teachers who attended the in-service teacher training programme developed by both projects, and as described below.

The same activities are to be developed again in a real context by kindergarten teachers who will not be attending the specific in-service teacher training programme. In the future, the assessment of kindergarten teachers' practices (in both cases) and of the activities' implementation process will serve to validate the proposed curriculum.

6.0 Links between projects

Project A is, in general terms, based on the assumption that kindergarten teachers must have the adequate subject content and pedagogical knowledge to support innovative science teaching. Project B assumes that a kindergarten curriculum must necessarily include a strong, consistent scientific dimension within a child-centred approach. These are crucial conditions to promote the development of children's scientific ideas in a constructivist learning environment that fosters scientific and technologic literacy. Learning activities should sustain and promote children's curiosity and enjoyment so that they develop a lasting interest in science. To accomplish such a task, it is necessary to teach teachers, developing adequate teacher training programmes and, on the other hand, teaching strategies should be available to kindergarten teachers, providing them with a curriculum to support their practices.

7.0 Teacher training programme presentation

The developed teacher training programme was entitled *S-T-S Education in Kindergarten – Importance of experimental work*, and its aims were to allow kindergarten teachers to:

- understand the relevance of and need for science education in the early years;
- (re)construct subject content and pedagogical knowledge;
- know international guidelines for science education – namely STS education; and
- promote the development of effective teaching strategies in kindergartens.

The teacher training programme was recognised by the Portuguese Teachers Continuous Education Council and was developed in Mirandela in the Bragança district, on a 3-hour/week-sessions basis, during the months of October and November 2009. It had a workload of 50 hours, of which 25 were of presentations/didactic teaching and 25 on an individual basis. Fourteen kindergarten teachers participated in this programme, with 6 participating further in the continuance of the current projects (A and B).

The programme's timetable is described in Table 3 overleaf.

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Table 3 – Teacher training program chronogram

Contents	Duration	Session typology
- Chronogram construction - Program aims presentation	3h	Group sessions (TP) – 12h Promote group interaction, dialogue, discussion, analysis, reflection…
- VOSTS questionnaire - S-T-S science education - Kindergarten science education and the development of children's competences. - Scientific competences	3h	
- Kindergarten in science education – recent studies - Different science education perspectives - Teaching and learning strategies – experimental work - Experimental work planning	3h	
Objects and materials	3h	Small group sessions (TP) – 12h Practical activities development and discussion.
Light	3h	
Forces and movement	3h	
Living things	3h	
- Activities development in kindergartens	25h	Individual sessions/work – 25h Activities implementation in kindergartens.
- Results communication and discussion - Assessment	4h	Group session

The programme's practical activities were organised in 4 thematic blocks, leading to the exploration of some relative concepts:

- *Materials and objects* – thermal conductivity, materials & objects, technology in toys and material diversity;
- *Light* – shadows, colour mixing, mirrors and light propagation;
- *Force & motion* – results of forces in toys, kinetic energy, friction and viscosity; and
- *Living things* – bees, living & non-living, germination and silkworms.

These activities were all varied in their typology (exploratory, sorting, illustrative, fair test, etc.), in the educational resources they require (daily lives, laboratory, etc.), their duration (from 1 hour up to 2 months), and in the scientific competences they could develop in children. Here follows an example of one of the activities, entitled *Just let me sleep!*

This activity is aimed at the development of a wide range of scientific competences, as described through the examples presented:

- *Content knowledge*: there are luminous and illuminated objects; we can only see when there is light; light can pass through an object/material or cause a shadow; different opacity of materials cause different shadows.
- *Science process skills*: such as comparing; identifying differences and similarities; inferring; interpreting information; and questioning.
- *Scientific attitudes*: such as showing interest in understanding the world; considering others' ideas and opinions; willingness to consider evidence and to change ideas; and perseverance.

The activity's framework is presented below in Figure 1, with the main aspects highlighted. The teacher's guide as presented to the teachers included all the aspects regarding this framework in the form of a consistent plan, which they could adapt to their own contexts. The different phases of the activity, as well as all the aspects regarding their development, are explained in detail.

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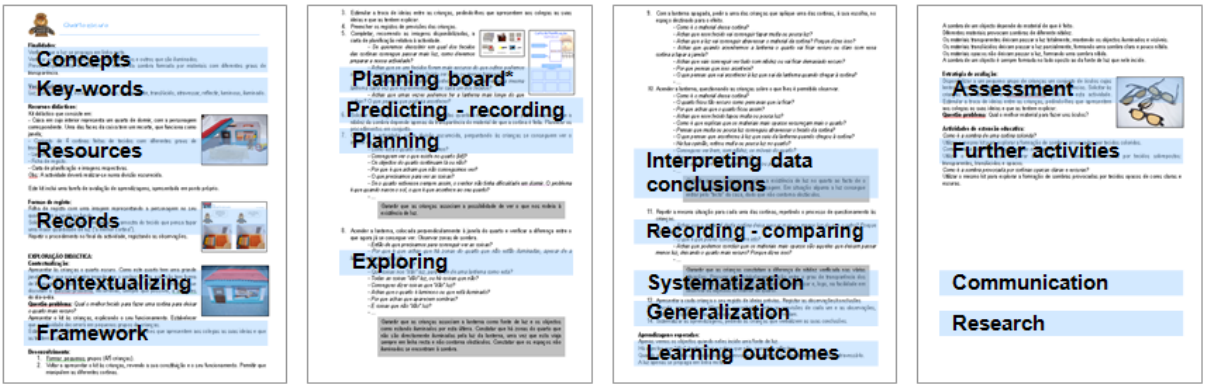
Figure 1 – Teacher's guide



This activity, as with all those developed for the programme, points to a communication phase, in which children can communicate to others (colleagues, classes, parents) what they did and what they learned, as well as an enquiry phase, in which they can search for more information about the subject matter. All the teacher's guides present a set of questions for the children, aimed at helping the teacher to stimulate children's thoughts and helping them to progress in their ideas.

All the proposed activities are flexible as can be seen by their frameworks, allowing the teacher to adjust some aspects of the methodology to suit their own groups of children. At the implementation sessions that both researchers witnessed, it was evident that teachers adapted some of the phases to their own and specific contexts.

This activity also includes a pack of educational resources containing everything that the teacher will need to develop it with the children. The resource pack consists of a box, made up to portray a bedroom complete with wooden furniture and a big open window, and also includes a flashlight and a set of four curtains made of fabrics of different opacity. The window is the starting point of the activity, leading children to suggest solutions for the problem faced by the activity's little man: What can be done to allow him to sleep during the day as his room is too bright and he works on night shifts?

The record sheet included in the pack shows two images of the bedroom and, on one of them, the children are asked to glue over the window a sample of the fabric that they think is best to darken the room – using their *ideas*. On the second image, they are asked to glue a sample of the fabric that they now see as best for that purpose – the children's *observations*. Included in the resource pack is also a planning board (adapted from Goldsworthy & Feasey, 1997), with a set of cards that have the different variables involved in this experiment illustrated through images.

With the help of the teacher, children try to 'read' the images and, after understanding their meaning, proceed to fill out the planning board on the correct places.

The assessment strategy consists of a set of four spectacles whose lenses have been replaced with the same fabrics used in the curtains of the bedroom. Children are asked to explain which one they think allows better vision, applying what they observed and learned in the practical activity.

8.0 Results of the teacher training programme

We believe that the kindergarten teachers found the teacher training programme to be important and adequate for their needs, leading to positive results in their practice reconstruction, by presenting new and innovative ways of teaching science. It was considered an important practical education programme in context, making them realise the need to continue attending science education programmes, and they understood that they are at the start of a long process.

With regard to the developed activities, these have been shown to be adequate for science education at kindergarten level, after minor changes in some. The concepts were considered appropriate and relevant, and the science skills and attitudes they demand of children adequate. In short, they were considered to be adequate teaching strategies and educational resources for the kindergarten science curriculum.

All this leads us to consider the relevance of continuous professional education to improving and extending ways in which science is taught and, simultaneously, about **c**hildren's functional understanding of some scientific inquiry processes and related science concepts.

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9.0 Conclusions

To conclude, we should consider, as an input to the whole process, the *teacher training programme* on one hand, and the developed *practical activities* on the other. Both were based on the shortcomings present in the science education at kindergarten level, namely, kindergarten teachers' *lack of development* and *lack of resources*. These shortcomings are frequently referred to by the research community as the main reasons for the paradigm existing in schools all over the world, and were also referred to by the kindergarten teachers who answered the questionnaire that preceded the development of the teacher training programme. Analysis of the questionnaires allowed the researchers to establish a programme that would provide an adequate response to these shortcomings, as perceived by the teachers, prompting changes in their practices.

This led to the development of a *teacher training programme* and a *set of teaching strategies*, intended to serve as an articulate and complementary means to support kindergarten teachers' subject content and pedagogical knowledge.

As far as the teacher training programme is concerned, we were able to gather evidence regarding the kindergarten teachers' gained knowledge to support the developed activities, thus leading us to consider the relevance of knowledge in science education. During the development of the teaching strategies, teachers made reference to the nature of science, to the way scientific knowledge is constructed. They promoted children's questioning and adopted group work as the basis of science-related activities. Some inconsistencies regarding language and concepts were observed, but the teachers showed an awareness of these and a willingness to invest in overcoming them, understanding the need of continuous and autonomous learning processes.

While considering the developed educational resources as adequate for the kindergarten level, some were complemented by additional resources from the teacher. Some of the teacher's guides were also adapted, giving them more pertinence to certain educational contexts. In order to do so, they took into consideration both the activities' purposes and their own groups of children, showing conceptual and didactic knowledge to sustain such changes.

Some difficulties were nonetheless encountered. The exploration of the planning chart and the children's records were stated as somewhat difficult to accomplish, mainly due to the fact that they demand certain competencies that both teachers and children were uncomfortable with mobilising. Science education is still in its early stages in the kindergarten curriculum.

On the other hand, and with regard to the developed *teaching strategies*, we were able to gather evidence to believe them to be a means to achieve good practice, allowing us to consider the relevance of resources to science teaching. The implementation sessions were audio-recorded and photographed which, along with handwritten data, allowed for an accurate transcription of events. Analysis of the teaching strategies was based on the evidence that children gave, through their behaviour, performance and words, of mobilising a specific set of skills, attitudes and values. Knowledge was ascertained by considering their responses throughout the activity and, moreover, during the assessment strategy, focusing on children's choices and justifications.

Throughout the different activities, children gave evidence of mobilising a set of skills, attitudes and values, while constructing new and more complex knowledge, as they later revealed in the respective assessment activities. Knowledge from previous activities was transferred to new ones, where children based their arguments and predictions on previous observations.

Analysis of the whole process allows us to conclude that the development of the teacher training programme, with the teaching strategies, is a relevant means to the improvement of the science curriculum provided to young children in kindergartens.

Closing remarks

Emphasising the scientific and technological nature of modern-day society, the research community agrees about the need for science- and technology-literate citizens. Therefore, the educational system must provide an adequate response to this global challenge, investing at the teacher, curriculum and resources levels, contributing towards a more universal science and technological literacy for all.

There is undoubtedly a need for adequate teacher training programmes, as well as adequate teaching strategies, fully supported by a curriculum. In this context, it is possible to conclude that a teacher training programme, such as the one presented in this paper, can show positive results when developed through co-operative work among researchers in co-related areas, contributing to the improvement of science education at kindergarten level.

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It proved to make a valid contribution to promoting change in science teaching in the kindergarten context, as it was based on the shortcomings as perceived by the teachers: lack of such in-service teacher training programmes and lack of specific teaching strategies to support innovative practices.

It also provides a clear example of how two of the recommendations made by Osborne & Dillon (2008) in their report to the Nuffield Foundation can be addressed. Science education must be sustained, on one hand, by good-quality teachers, with up-to-date knowledge and skills, as the foundation of any formal science education system and, on the other hand, by innovative curricula and ways of organising the teaching of science that are required to improve the science and technology literacy levels of the next generations.

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