

A Science Teacher Education Course in a Science Centre: A Successful Strategy to Empower Teachers to Master Museum Resources Exploration?

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Abstract

The main objective of this study was to understand the impacts of a science teacher training course, designed and implemented in a science centre, in teachers' exploitation of the opportunities inherent to science centres learning contexts, through the evaluation of its impact. Data were collected through direct observation of the tutorial sessions and the school-visits organized and implemented by seven teachers. An online questionnaire was administered to 38 participants in order to understand their perspectives of the course. The data were triangulated in order to make an evaluation of the course according to its effectiveness, efficiency, relevance and durability. Data showed that the development of a science teacher course by a science centre, proved to help teachers to capitalize on the opportunities these non-formal institutions offer to enrich and reinforce science school learning. Some improvements were suggested in order to achieve a greater effectiveness.

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Introduction

Science education trends converge in suggesting a need to (a) promote a deep understanding of science and technology, (b) develop applied knowledge on fundamental scientific concepts, and (c) support awareness of science methods and their relations with other domains of society (EC, 2007; Osborne & Dillon, 2008). Science teaching needs to be more effective in 1) increasing students' interests and attainments in science; 2) promoting the use of intellectual skills, like critical thinking, in addition to knowledge acquisition; and 3) providing opportunities to develop and use a range of complementary skills, such as collaborative and communication ones.

Non-formal science institutions, such as museums and science centres, can contribute greatly to these goals. Their mission is to support public engagement with science and technology, contributing to the development of a more scientifically literate citizen. Moreover, by strengthening school science, through the implementation of collaborative actions with schools or science teacher training institutions, science museums and science centres can contribute to the creation of a more interested and receptive audience for future and lifelong science learning, playing an important role in the reform of science education (Chin, 2004).

The learning environment in these institutions has potential advantages in nurturing curiosity and improving motivation, interest and enthusiasm to learn (Anderson, Lucas & Ginns, 2003; Falk & Dierking, 2000; Ramey-Gassert, Walberg & Walberg, 1994). In these environments learners can control their own learning agenda (Bell, Lewenstein, Shouse & Feder, 2009; Hofstein & Rosenfeld, 1996) while assuming an attitude of active learning and experiencing different relationships between science, technology and society (Falk & Dierking, 2000; Jarvis & Pell, 2005; Ramey-Gassert et al., 1994).

Schools can exploit the learning potential of these institutions through school visits to the centres. However, research has shown that school visits to science museums and science centres are often conducted in a manner that do not maximise the learning opportunities they could afford (e.g. Kisiel 2006; Kubota & Olstad, 1991). The last decades of research on the learning that can result from these visits has produced a series of recommendations for teachers to enhance the effectiveness of such experiences in promoting learning. Teachers are encouraged to become familiar with the setting before the visit, to orient students to the setting and learning agenda, clarifying the objectives of the visit, to plan pre-visit and follow-up activities, to allow students time to explore and discover during the visit and to plan activities that support the curriculum (DeWitt & Osborne, 2007).

However, these recommendations seemed to be rarely followed by teachers (e.g. Griffin, 2004; Griffin & Symington, 1997). In general, there seems to be a gap between school-based and museum-based activities that is a major impediment for students' learning in a visit (Tal & Morag, 2007). In order to effectively integrate formal and non-formal practices, supporting good practice among teachers, and maximising the educational potentialities of science museums and science centres, the building of collaborative actions between schools and these non-formal institutions for educational purposes is necessary.

Teachers are well placed to meet challenges and capitalize on the opportunities inherent to the museum free-choice learning environment, conducive to exploration and discovery (Falk & Dierking, 2000; Griffin, 2004; Mortensen & Smart, 2007). However, both initial and in-service science teacher programs are needed in order to guide teachers to design and implement effective visits and to integrate non-formal resources in teaching practice. On the other hand, museum education staffs need to develop suitable strategies in order to facilitate student learning, and to empower teachers to master strategies based in museum resources (Chin, 2004).

Integrated in these current movements to reinforce the collaboration between non-formal institutions and the formal educational system, the Portuguese National

Agency for Scientific and Technological Culture (“Ciência Viva”), created a teacher training course: “The use of Science Centres as resources for science teaching in elementary education”. This agency co-ordinate a network of science centres distributed throughout the country.

Course description

The tutorial unit of the course includes four sessions (of 4h each). During the sessions teachers were always instructed to develop small group-tasks based on the different themes under discussion. Each session is outlined below.

Session 1: "Formal and non-formal learning environments"

Within this session, teachers were invited to develop a several activities aimed at promoting a closer view about the uniqueness of the learning context of the science centre, in contrast with schools’ contexts, and exploring the necessity of diversifying the strategies used in exploring it.

First, teachers were asked to critically evaluate an interactive exhibit, assessing its adequacy in view of their future audience, students of a specific age. The purpose of this task was to promote a critical analysis of the resources in the science centre, stimulating a deep consciousness about the need to adopt different strategies to foster a proper exploration by students of different school years and ages.

Secondly, teachers were invited to discuss and reflect on similarities and dissimilarities between formal and non-formal learning contexts. At the end, teachers had to sort a series of activities as being characteristic of a formal or non-formal environment and to discuss their own choices.

Session 2: "How to organize a school visit?"

This session was intended to promote teachers' awareness of the need to prepare in advance so that the school visit would take place in an organized way and simultaneously create a shared understanding of the purpose of the visit.

As a first activity, teachers had to choose one goal (from a list provided) for a study visit to a science centre and to justify their choice. This activity was intended to enhance the importance of stating specific and achievable objectives when designing a school visit to a science centre.

Teachers were then invited to critically examine different proposals of experimental activities offered in the exhibition. Beyond the question of the need to develop appropriate strategies for each school level (already explored in the previous session), the teachers explored the need for teachers to know the exhibition before the visit with their classes. This knowledge would allow them to prepare the activities to their students’ needs, helping them taking the maximum advantage of the resources available.

As a third activity, a pair teachers were required to manipulate an exhibit with one of them having his/her eyes closed. This activity explored the need to tailor

different strategies according to the diversity of students, namely taking into consideration different needs and interests. On the other hand, it strengthened the need for the teacher to act as a mediator in the way the different experiences are seized by different students. Moreover, it also stressed the importance of students exploring the exhibition to be conducted in groups.

As a fourth activity teachers were asked to plan an activity, subjected to a certain thematic of their choice, based on the resources present in the exhibition. This activity aimed at stressing the need to previously structure each activity, and then look for adequate strategies to explore the existing resources in a way to accomplish the proposed objectives. Finally teachers were asked to prepare a presentation using the resources available online regarding the science centre, so that their pupils will know in advance the physical setting of the science centre, reducing the impact of the novelty and the unknown inherent to any visit to a new place.

Session 3: "During the school visit"

Within this session, teachers were invited to reflect on the role of the different intervenient in a school visit: students, teachers and science centre educators.

As a first activity, teachers were invited to critically evaluate two practical demonstrations about the role that a science centre educator can take. During the first demonstration, the science centre educator asked teachers about the experimental activity they were carrying on, in a provocative and inquisitive way, stimulating teachers' critical view about what they were doing. During the second demonstration, the educator assumed an extremely authoritarian position, performing the experience without requiring any intervention on the part of assistants and not answering any questions raised by them. With this activity teachers were asked to reflect about different strategies which may or may not promote reflection, curiosity and greater motivation on students towards certain activities. As a complement to this activity, a second activity was developed in which teachers were asked to classify different resources available in the science centre according to its degree of interactivity (a notion that was also discussed during this session). This activity aimed at promoting teachers' awareness about the relevance of their pupils to move from passive observers to active performers.

As a third activity, teachers were asked to associate certain daily images to a given exhibit according to the phenomena under analysis, in order to emphasize the need to encourage their pupils to develop different strategies to explore the exhibit so that they will gain some sense of their own.

Finally, teachers were asked to propose and discuss a possible worksheet to guide the exploration of a particular exhibit taking into consideration the different aspects discussed during the session in relation to students' roles. This activity was intended to highlight the need to give support to students when manipulating the exhibits.

Session 4: "Evaluation of the school visit"

This session was intended to promote teachers' awareness of the need to evaluate school visits, in all its phases (before, during and after the visit).

As a first activity, teachers had to choose one parameter (from a list provided) to assess a study visit to the science centre and justify their choice. During this activity teachers explored the possibility of evaluating different impacts of a given school visit according to its main objectives, namely its impact on students' knowledge acquisition, their attitudes toward science, and the development of certain competencies.

Finally, teachers were invited to create one worksheet for a hypothetical visit about one specific subject (following a protocol supplied). They were required to explain it to the rest of the group, enabling a reflexive discussion about the potentialities of presented proposals.

This course is now being implemented in different science centres within the network and may come to assume an important role in contributing to closing the gap between schools and these non-formal institutions. For this reason, it is essential to understand their impacts in science teachers training.

Methodology

Teacher training course

The study was conducted in a Science Centre at Amadora, near Lisbon (Portugal), an interactive Science Museum intended to be an interactive space of science and technology. This Science Centre is part of the Ciência Viva network and it is dedicated to the science of everyday life, especially with science in our homes. Its main objective is to promote the dissemination of scientific and technological culture among citizens. The purpose of the present study was to contribute to the understanding of these issues through the evaluation of the teacher training course, trying to analyse its impact in the organization and implementation by teachers of a study visit to a science centre. Of specific interest was the examination of the course according to the following criteria:

- Effectiveness: teachers' performance corresponded to the objectives defined;
- Efficiency: the strategies and the resources were the most appropriate;
- Relevance: the course was related with teachers needs and responded to real problems;
- Durability: its effects could be extended to the organization of school visits to other science museums and science centres.

This course was created in 2007 and implemented in the science centre under study in 2008 for the first time. The course included a tutorial unit, corresponding to 16h of theoretical and practical work in class and an autonomous unit, corresponding to 10h of autonomous work. To complete the autonomous unit, teachers had to develop a portfolio and to organize and implement two visits to a science centre. The course was directed to elementary teachers and its attendance afforded teachers with professional credits, for professional progression.

Participants

A total of 38 teachers, distributed in classes of nine to ten participants each, attended this course during the study period. They were all elementary teachers of children six to ten years old: ten teachers taught first grade pupils (6 to 7 years old); seven teachers taught second graders (7 to 8 years old), eight teachers taught third graders (8 to 9 years old) and 12 teachers taught fourth graders (9 to 10 years old). One of the teachers had a professional background in special education, giving pedagogical support to children with special educational needs.

Data collection and analysis

Data were collected in two ways: a teacher survey and observations of the course and of visit to the centre. With the purpose to analyse the impact of the training course on participant teachers' professional development they were asked to answer to an online questionnaire addressing their opinion about the relevance and adequacy of the course they attended. All 38 teachers involved in the study answered to this questionnaire. The open-questions of the questionnaire were analysed through a method of content analysis. We followed an inductive process in which the categories emerge from data (Miles & Huberman, 1994).

Non-participant and naturalistic observations of all the sessions of two of the classes were conducted by one of the researchers in order to describe the teacher training course and to obtain information about the themes focused and the work developed. Both classes had the same instructor.

In addition, observations of the school visits organized by the teachers who participated in the course were conducted by one of the researchers. This observation provided data about the organization of the visit, the role played by the teacher and students' involvement. Seven school visits were observed.

The design used for the observation followed a scheme specifically designed for this study. The observation was organized into two distinct but interrelated phases: a descriptive phase, in which the observations were free (unconstrained), and served as a basis for direct observation in subsequent stage; a structured phase, in which the observation was directed to aspects under study that were previously recognized as the most relevant (in the unconstrained phase) (Gall, Gall & Borg, 2007).

For the analysis of observational data we used a method of content analysis. Through an iterative process, of reading and re-reading data (Miles & Huberman 1994), we assigned meaningful pieces of text to previously defined aspects considered relevant: group organization, type of interactions established between each actor involved and with the objects in the exhibition, dialogues, and some nonverbal indicators, such as the spatial location of the various actors and the "posture" assumed by each one (enthusiastic, alert, inattentive, bored)

Results

School-visit description

The vignette bellow provides a description of a visit based on observation data collected during a tour with third grade pupils.

Vignette: (14h; 20 students of the third grade).

The group arrives at the exhibition room. The teacher reviews with the class the rules of conduct during the visit. The whole class follows the teacher for a very brief visit to the exhibition space (about 5 min.). Pupils seem very excited and curious about the exhibition. Each group, previously formed, goes to a specific module (everyone seems to know where to go). All students have a worksheet. The working rule is for each group to first explore the exhibit and try to fill out the worksheet. All questions in the worksheet seemed mostly related with the labels (that can be answered merely by searching written information), and not to the objects in the module or with the explanation of the phenomena dealt in the module. Students began to show they were lost; seeming that they were not able to realize the purpose of the worksheets and where to seek for information. They are constantly asking their teacher about what they have to write. The teacher seeks not to give them the answers. She goes through all the groups, asking students about what they are seeing, challenging them to reflect about the exhibit. As soon as a group filled the worksheet, they started an experimental activity associated with the exhibit. Students do not seem familiar with an experimental protocol. They seem very excited with the experimental task. They ask the teacher how to do the experiment, ignoring the protocol. Finally, they seem to understand that they must follow the protocol. They execute the guidelines given in the protocol but they do not record any data, nor conclude anything about what they are observing. After finishing the experiment they walk around the exhibition room, trying to check what the other groups are doing. The visit is over (15h). All groups completed the worksheet.

In all school-visits observed, it was evident that students were previously presented to the science centre, either through photographs or using the institutional website. They seemed aware about the exhibition, and its resources. Students were organized in groups before starting the visit and all of them seemed aware of the rules of conduct to follow during the visit.

Firstly, at the beginning of all visits observed, students were invited to become familiar with the exhibition, before they began to exploit it. However, in most visits, this familiarization time was extremely short, taking the format of a simple "walk" across the exhibition room (lasting less than 5 min.).

In all visits observed, students had to complete a worksheet, usually with a very rigid structure (following a format similar to the examples given in the tutorial sessions). The closed questions in majority did not allow great choice in what information is sought. Almost all information required was present in the exhibit labels. The limitations of this worksheet became evident, since it was fully focused on information search, in detriment of promoting students' reflection and interpretation of the objects and phenomena observed. Many students seemed do not realize the purpose of the worksheet itself, either because they did not understand the questions and the kind of answers they were expected to give, or they did not know where to look for the information. All visits ended without a group discussion, where students could exchange their experiences and reflect on what they have learned.

In all visits teachers assumed an active role seeking to assist all groups exploring the exhibit and completing the worksheet. Most teachers tried to trigger students' discovery and searching for information through continuing questioning about what they were observing.

Students seemed extremely curious at first, raising many questions and demonstrating an eagerness to explore all the resources, and to fill the worksheets. However, as time was going by, they seemed more and more demotivated, especially those who did not understand the purpose of the worksheet. One interesting aspect observed, was the total unfamiliarity of students in performing the experiments proposed. Although they all showed a strong motivation to perform the experiment, they seemed unprepared to follow an experimental protocol and they showed lack of interest in the explanation of the results after performing the experiment.

Teachers' evaluation of the course

In general, teachers' overall appreciation of the course (table 1) was high or very high concerning its level of interest (95%), "understandability" (100%), applicability to school contexts (92%) and to other science centres (97%), and relevance for scientific (92%) and for pedagogical (97%) enrichment.

Table 1.

Teachers overall appreciation of the course (n=38): (1) very low; (2) low; (3) high; (4) very high

<i>Evaluate the course according to its level of:</i>	1	2	3	4
Interest	0	2	19	17
Understandability	0	0	24	14
Applicability to school contexts	0	3	19	16
Applicability to other science centres	0	1	23	14
Relevance to scientific enrichment	0	3	26	9
Relevance to pedagogical enrichment	0	1	24	13

When questioned about the aspects not accomplished in the teachers emphasized the need for more hours because of the complexity (many scientific concepts) and diversity of the themes explored (seven teachers), and some inadequacy of the strategies explored to very young children (6 to 7 years old) (three teachers of the first grade). Three teachers revealed that the course didn't attain its main objective. One criticized the fact that she was unable to implement the visit explored in the tutorial sessions with her students, which probably means that she misunderstood the main purpose of the course, and two referred that it didn't help them to achieve a suitable plan for a school visit to a science centre.

The reasons teachers gave for attending the course were mainly related with their professional needs (see table 2), namely pedagogical (89%) and scientific (76%) training. Another reason was the fact that the course affords professional credits, which are important for their professional progression (89%).

Almost half the participants (45%) had never designed a school-visit to a science centre before attending the course (see table 2). The reasons they highlighted were mainly related with their general unfamiliarity with the exhibitions (59%) and the complexity of the scientific knowledge usually involved (53%). The majority of them also highlighted the intensive extra work needed for organizing a school visit (71%).

At the end of the course, almost all participants considered that their confidence (84%) and willingness (92%) improved in which concerns organizing school-visits to science centres (see table 2). When questioned about what has changed in their perspective on the organization of school-visits to science centres, many teachers referred a greater awareness about the need for a closer attention for the visit preparation (19 teachers). They also referred some aspects related with the development of the visit itself (seven teachers), namely a greater awareness about the importance of teachers behaviour (two teachers) and educators behaviour (one teacher) during the visit. Two teachers referred the importance of connecting the visit with the work developed in classroom and two referred the need of evaluating students learning. Some teachers (eight) referred a general impact on their vision about school-visits, awakening them to the need to make a better use of the visit according to its numerous potentials.

Table 2.
Teachers' evaluation of the course (n=38)

<i>Reasons for your participation in the course:</i>	Yes	No
Course of few hours	15	23
Meets a pedagogical need	34	4
Meets a scientific need	29	9
Course with professional credits	34	4
To keep company with colleagues	10	28
<i>Did you have already organized a school visit to a science centre?</i>	21	17
<i>If you answered negatively, give your reasons:</i>		
It is difficult because I don't know the exhibitions	10	7
It is difficult because of the complexity of the scientific knowledge involved	9	8
It is difficult because of the intensive work that involves	12	5
It is difficult to promote the involvement of all students	5	12
<i>With this course you:</i>		
Become willing to organize school visits to science centres	34	4
Feel easier to organize school visits to science centres	35	3
Continue to have difficulty in organizing school visits to science centres	6	33

Discussion

On the whole the teacher training course that was object of this study was well organized, following a structure suited to the stated objectives. Most of the activities and materials used were suitable to achieve the purposes for which they were built (efficiency), and according to the questionnaire results, the course was in fact related to the teachers' needs (relevance). Concerning their impacts, in general it seemed that the

course achieved its main goals, since teachers stressed the fact that they feel they have become more capable and more willing to organize school-visits to a science centre (effectiveness). Moreover, they became more conscious about the importance of their role during a school-visit, performing in all visits observed a very active attitude, intervening and guiding pupils' explorations.

However, some issues were identified that can be improved in order to achieve a greater effectiveness and to assure that the course's effects can be extended to visits to other science centres (durability):

- To promote a deeper reflection on the possibility to diversify the strategies to be applied in non-formal contexts.

In the first session, teachers discussed and reflected about the specificities of each learning context involved, classroom and non-formal one. However, this idea can become more meaningful if explored the possibility to create in a science centre environment learning situations with different characteristics (e.g. more or less structured, with more or less autonomy for students), depending on the intended learning objectives, in order to illustrate the possibility to use diverse pedagogical strategies regardless the contexts in which they occur. Indeed, non-formal settings occupy an important and unique space in science learning, presenting strengths that are unique and complementary to the strengths of schools (Bell et al., 2009; Jarvis & Pell, 2004; Pedretti, 2002; Ramey-Gassert et al., 1994). Learning science in non-formal environments is a diverse enterprise and serves a broad range of intended outcomes, like inspiring emotional reactions, reframing ideas, introducing new concepts, communicating the social and personal value of science, and promoting deep experiences of natural phenomena (Bell et al., 2009).

- To highlight the need for more meaningful school visits to the students, for example as a follow-up of specific subjects worked in the classroom, and so as a way to search for certain answers related to questions arising in the course of this work, or rather, to trigger interest in a new theme to be explored in upcoming classes, instead of merely exploring the need to address aspects related to organizational issues and reduction of novelty.

In the second session, emphasis was given to aspects related to reducing the "surprise effect", by presenting to students the physical setting and discussing with them some organizational issues, such as the rules of conduct and their organization in groups. A key educational challenge for science museums is to link emotional and sensory responses with science-specific phenomena. Associating scientific thinking with engaging and enjoyable events and real-world outcomes can create important connections on a personal level (Bell et al., 2009).

- To promote the development of ways to explore science centres other than the use of worksheets, for example inquiry and problem solving strategies, and emphasize the importance of students' free exploration time during the visit.

The worksheets created by teachers, which were based on models proposed during the tutorial sessions, proved to be very rigid and with little adaptability to the diversity of students' interests and competencies. Active science learning, in which

students are engaged in inquiry, problem solving activities, investigating and experiencing relationships between science, technology and society, is extremely important in formal as well as non-formal settings (Bybee, 2001; Hofstein, Bybee & Legro, 1997). Teachers should provide open-ended tasks to be carried out by their students at the science centre that require observation, discussion and deduction. These methods are more effective at all school levels in increasing students' interest and achievement, promoting the use of intellectual skills, like critical thinking and reflection, in addition to knowledge acquisition. On the other hand, they provide opportunities to develop and use a range of important complementary skills, namely collaborative and communication competencies (Bybee, 2001; Hofstein et al., 1997; Jarvis & Pell, 2004).

- To work with students the importance to interpret and discuss the results obtained in experiments and give greater emphasis on the importance of having a time to exchange experiences among all participants.

This issue can be better explored, for example, when reflecting about the importance of asking students to explain to their colleagues at the end of each visit what they have performed and observed, promoting a final period of joint reflection about what they saw, what they discovered and what they want to know more. There is substantial evidence that social interactions among visitors may be important in stimulating learning (Diamond, 1986). These environments are ideal for the development of science concepts since there is an emphasis on hands-on activities related to real-world objects and events, with social interaction and group performance emphasized (Falk & Dierking, 2000; Jarvis & Pell, 2004; Ramey-Gassert et al., 1994). The learning in science centres, that is characterized as learner-centred, self-regulated and situated, actively involves peers in social interactions (Hofstein & Rosenfeld, 1996; Ramey-Gassert et al., 1994). Teachers should create mechanisms for students to search information and to interact with peers, whereas interacting with exhibits, as a way to support and value appropriate play with the exhibits, while promoting social interactions directed to the understanding of the science topics under observation (Jarvis & Pell, 2004).

In conclusion, the development of a science teacher course by a science centre, in which participants can critically discuss different aspects of the exhibitions with the science centre educators and can design school visit plans to be implemented in the museum setting, proved to help teachers to acquire more in-depth knowledge about the museum resources, to gain deep consciousness about the importance of knowing the exhibitions before planning their school visit, to assume a more active role during the visit, and so to capitalize on the opportunities these non-formal institutions offer to enrich and reinforce science school learning.

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