RoJEd

Romanian Journal of Education

Volum 1 number 3-4
Page 93 – 102

A REVIEW OF THE USE OF DEMONSTRATION LECTURES IN THE PROMOTION OF POSITIVE ATTITUDES TOWARDS, AND THE LEARNING OF SCIENCE WITH REFERENCE TO 'A POLLUTANT'S TALE', A DEMONSTRATION LECTURE ON AIR QUALITY AND CLIMATE CHANGE

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Abstract: The lecture demonstration is a vehicle that is often used in public engagement activities to promote positive attitudes towards science and the learning of science. In this paper we review evidence that supports this assertion. In addition we focus on a lecture demonstration entitled 'A Pollutant's Tale' that examines some of the chemistry of the gases in the atmosphere and aspects of climate change and critique its effectiveness on the impact of demonstration on the learning of science concepts and attitude towards science.

Key words: Chemistry outreach, public understanding of science, lecture demonstration, School Teacher Fellow, cryogenic materials.

"The laboratory sets science apart from most school subjects…communicating understanding of, and the skills associated with, scientific methods. Without laboratory, it would be difficult for students to comprehend what scientists do". [1]

1. Introduction

The purpose of this paper is to provide an overview of the relevant literature directly and indirectly related to this study, highlighting particular areas of importance, weaknesses or gaps in the current research in this area. One of the goals of out-of-classroom learning is to make up for the limitations of formal education experiences by designing activities in such a way that is not common or possible in the normal classroom context. We present the theoretical background that supports the role of lecture demonstrations as an effective tool in promoting science learning and in promoting positive attitudes towards science and discuss the impact of a lecture demonstration, 'A Pollutant's Tale', in this context.

2. The Lecture Demonstration

In this paper '*Lecture Demonstration'* is used to describe a scientist in a lecture theatre setting; describing and carrying out a series of experiments which demonstrate a scientific concept or

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Published: 30 December 2010.

concepts. The 'lecture theatre setting' may also include a school hall in a school. Demonstrations have always been fundamental in helping people to understand scientific discoveries and concepts. Taylor [2] cites the words of Sir Lawrence Bragg, a member of the Royal Society and a Nobel Laureate in Physics in 1915

"*It is surprising how often people in all walks of life owe that their interest in science was first aroused by attending one of these courses (demonstrations) when they were young, and in recalling their impressions they almost invariably say not 'we were told' but 'we were shown ' this or that'*.

Visual and sound effects have had an impact on the learning of science for many decades – indeed centuries as they were also used by Galileo and Faraday. It is understandable that the nature of this type of demonstration has become a key aspect of science teaching and learning, and why organisations use them to engage younger learners in their outreach programmes.

The inspiration that prompted this work was '*A Pollutant's Tale'*, a lecture demonstration designed and delivered by the Bristol ChemLabS outreach team [3,4]. This lecture demonstration describes the composition of Earth's atmosphere and compares it with the other planets in our solar system; a brief description of the structure of the Earth's atmosphere; investigation of some of the chemistry and properties of nitrogen and oxygen; and a few of the tropospheric (approximately lowest 10 km of the atmosphere) pollutants including carbon dioxide and nitrogen dioxide. This demonstration lecture involves a series of experiments involving liquid nitrogen, oxygen foam, dry ice (solid carbon dioxide) and a few explosions [5]. It is normally delivered in 50 to 75 minutes depending on the age and nature of the audience. For instance, the topics on tropospheric pollutants and climate change are normally covered in greater detail for the pre-university, post-16, senior students, but are not covered in the detail for students aged 14-16. Members of the wider community such as scouts and church groups have also experienced this lecture demonstration. The lecture demonstration is also used in international outreach visits to Australia, Spain, South Africa, Hungary, Malta, Jersey, China, France and Ireland and is performed on average three times per week in term time by the Bristol chemists. Recently the lecture has also been adopted, after suitable training, by the Chemistry Department at Rhodes University whose postgraduates take it into township schools and by demonstrators who perform it several times per week at the Sci-Bono Science Centre in Johannesburg.

Taking into account the inaccessibility of cryogenic substances such as liquid nitrogen and dry ice in UK schools (and indeed in schools across the world) due to perceived safety issues, cost and lack of appropriate equipment, Bristol ChemLabS devised "*A Pollutant's Tale*" and the primary version "*Gases in the Air*" based on it. The latter is normally performed for children aged 4 to 11, in a form of school assembly in the primary schools themselves. Cryogenics-based demonstrations can dramatically illustrate transformation properties of materials associated with temperature variation as they can be astonishing for the learners and be useful devices for emphasising changes of state and whether or not a physical or chemical change has taken place.

3. The Learning of Science Concepts

In researching the impact of the lecture demonstration on the learning of science concepts, it is essential to be clear what is meant by 'learning'. Learning has been defined in numerous ways over the years. This study is largely based on constructivist theory of learning, using the ideas of Piaget [6,7] and Vygotsky [8] but a full discussion of the theories and definitions of learning is beyond the scope of this paper. With the nature of the activities in the present study, the students are engaged in the *minds-on* and some with *hands-on* as well. According to Sylwester [9], the change in physical environment to a stimulating social learning experience during the outreach activities can lead to a positive effect on the physical development of the brain. Wolfe & Brandt [10], on the other hand indicate that the richness of stimuli in the environment which allows social interactions between students, will offer the learners many opportunities to relate new knowledge to their existing knowledge, which is mostly derived from formal schooling. For each activity in this study, the learners play an active role in their learning process [11] and in order to have a meaningful learning experience, they need to be intellectually involved [12].

During the cryogenics-based demonstration, the students are encouraged to predict and explain the outcomes of each experiment, with the support from the demonstrator, who does the '*scaffolding'* as suggested by Vygotsky [13] by asking leading questions catering to distinct cognitive levels and relating to specific topics covered in the General Certificate of Education (GCSE, England and Wales national examinations at 16 years of age) or Key Stage 3 (KS3, England and Wales students aged 11-14) chemistry syllabus and in the case of primary school KS2 (England and Wales students aged 8-11), the general science syllabus. This will encourage the learners to activate the needed schemas or knowledge for possible assimilation or structuring. Demonstrations such as those with liquid nitrogen and dry ice which are not normally seen in a classroom setting need to be relevant to the students' existing knowledge in order to have an optimum impact on learning and are consistent with the Piagetion concept of knowledge construction.

Similarly, based in the context of the university outreach centre, this study is also grounded on a theoretical framework known as "*situated cognition*" [14-17] Situated cognition is described as:

"*… learning is deeply contextualised, mediated, and therefore shaped by the physical, social and political landscape in which it occurs…. beyond the individual learner…to consider, for example, the people with whom he or she interacts, the physical and cognitive tools he or she uses, the physical space within which he or she works, the roles he or she assumes as he or she learns and how these, to greater or lesser degrees address a void in his or her learning experience."* [18]

4. The Impact of Demonstration on the Learning of Science Concepts and Attitude towards Science

Several notable studies have assessed the impact of the lecture demonstration on students. After a lecture demonstration, Beasley [19] found an increase in levels of attention and task involvement, while Buncick *et al* [20] noted increased participation. A study by Bogen [21] revealed a greater appreciation of science and increased motivation to pursue careers in science. Other studies have highlighted more specific impacts of the lecture demonstration on students. Arousing curiosity is the key to enhancing learning. Lecture demonstrations are able to achieve this. Gardner [22] states that they allow learners to have an "*aha*" experience, which increases their curiosity and enhances their reasoning abilities, in turn impacting on students' achievement in the classroom [23]. Fun and enjoyment are also described in the research as a positive impact of lecture demonstrations. Morris [24] believes that if science is enjoyable, this will have an impact on the child's learning of science in the long term, which could ultimately impact on their career choice. Flow, a state described and captured by Csikszentmihalyi [25] is a state of intrinsic motivation experienced by people fully engaged in an activity and can be encouraged through the use of lecture demonstrations.

On the other hand, demonstrations that use cryogenic substances have shown greater positive impact on students. A higher percentage of the students in a study by Lopez-Garriga *et al* [26] agreed that these types of activities kept their attention, while at the same time they also wanted to be more informed about scientific principles behind the demonstrations. In addition, the majority of them agreed the demonstrations had increased their interest in science and would like to see more demonstrations in the future (*ibid*). Similarly, a study by Lee and Schreiber [27] shows that the demonstration is '*an eye-opening experience*' for the students, where, not only do they get excited; they also feel encouraged to further their career interest in science. An evaluation on the outreach programme that comprised of workshop, hands-on-activities and cryogenics-based demonstrations have been shown to arouse students' and teachers' interest in science and its applications [28]. In this study, almost all the teachers requested more outreach in order to supplement their teaching resources needed for their science lessons and as an innovative way of capturing the audience.

These types of demonstrations also reveal that there is an immediate improvement in the learning of science concepts, as well as attitudes towards science among the students regardless of the learning abilities and gender of the students [29]. Interestingly, the follow-up impact indicates that the cognitive gain on the scientific concepts remained generally stable within two weeks after the field trip [30] which coincides with other findings [31-33].

However, it is important to note the potential problems in ensuring demonstrations are used to their full potential. Shepardson *et al* [34] cites several reasons why this might not happen. These include the interference that prior topics can cause and, if the demonstration is not set up adequately, confusion resulting in an inability to view experiments clearly. Roth *et al* [35] emphasised the need for students to be guided as to which aspects of the demonstration to pay attention to. Traditionally, lecture demonstrations aim mainly at the explanation of the scientific concepts, which are nowadays called pubic understanding of science, as evidence from this excerpt:

"Success in the lecture theatre was until the last quarter of the nineteenth century a necessity to any scientist… Faraday's lectures were a communal experience, not just an individual one. He …[Faraday]…appealed principally to the imagination, both public and scientific, quickening his audiences to a new capacity for experience"[36].

Today, however, the aims are no longer seen as explanation of scientific concepts, but rather as 'entertainment at the expense of explanation' which also concentrates on 'the marvellous and the mystical' [37]. Studies on live science shows or demonstrations carried out in the UK, USA and Australia, ranging from varieties of chemistry topics such as reduction-oxidation (redox) reactions, polymer chemistry, acid and bases, etc, seem to focus on the impact of sound and visual, rather than underlying the scientific ideas (*ibid*). The authors abhor the term 'chemistry magic show' which is judged to reflect the latter rather than the former type of lecture demonstration. The whole point of performing such lectures is to explain aspects of science and not to baffle. Tuah [38] shows the impact of the students' learning of science concepts were boosted by 'the role of the demonstrator in '*scaffolding'* the knowledge through the repeated use of the key-concepts delivered and relating them to the chemistry' that they are expected to learn. According to Roth *et al* [35] students need guidance in which aspects of a demonstration that they should pay attention to. The demonstrator role is of prime importance in ensuring links are made to students' existing knowledge if there is to be a maximum impact on students' learning. The results of several hundred questionnaires received from students and teachers captured after numerous demonstrations of A Pollutant's Tale have shown that the two-way interaction between the lecturer and the audience was an important feature of the perceived success of the Pollutant's Tale format in reinforcing science concepts. A variety of presenters have given this demonstration lecture over the past three years and it is also worth noting the impact of young role models, particularly with teenage audiences in terms of engendering positive attitudes towards science.

5. The Role of the Teachers

Regardless of the type of venue or place for school fieldtrips, teachers' reasons for organising fieldtrips are generally similar. Teachers play a pivotal role in their students' learning experience during any fieldtrip. Literature on science museums or centres has been understandably the most studied out-of-classroom learning and the most popular destinations for school visits. However, the lessons learnt from studies of the roles of teachers at these venues are beneficial and will be selectively reviewed to support the context of this paper as there is not much written on the roles of teachers for fieldtrips to universities.

DeWitt & Osborne's [39] study indicates that teachers' motivation when organising fieldtrips is consistent with what research has shown about the potential of these types of visits to support learning, whether for connecting to the curriculum (conceptual learning goal) or enjoyment, and enhancing interest and motivation (affective learning goal) [40]. Conversely, research also indicates that fieldtrips are often not conducted in such a manner that maximises the learning that can result from them [41-42]. Their success, to a large extent, reflects on the teachers' pre-visit and post-visit activities, as well as their involvement during the visit. According to Rennie & McClaferty [43] the initial planning is crucial. Teachers need to consider the actual purpose of the visit itself. Meanwhile, Rickinson *et al's* review [44] indicates that out-of-classroom learning of any kind is most effective with adequate preparation and follow-up. In addition, Rennie [45] suggests that teachers include a pre-visit to the intended venues, communication with the people in-charge as well as preparing students by giving information on what to expect and the overall outline of the visit.

Clearly, the teachers' role in learning is paramount with regards to how they prepare for the visit and how they incorporate the resources and experience back into their classroom. Failure to do this adequately will limit the full impact of the experience. Several studies on learning visits to museums specifically focused on the role of pre and post-visit activities as potential contributors for enhancing the learning experience [46-48]. What may be learnt from these studies is that the pre-visit activities activate students' prior knowledge which can assist in the understanding of experiences at the venue. Also post-activities reinforce new connections and complement students' future learning experiences [49]. Whilst post event follow up is in the domain of the teacher, the provider of the lecture demonstration can make available information to assist the teacher in planning the visit such as a general risk assessment for the venue, any PowerPoint that is used [4] and access to some or all of the practical details and other backup material [5]. Many of the practical demonstrations may be new to the accompanying teachers, particularly those who have entered the period of teaching where the introduction of risk assessment resulted in less of the dramatic experiments being passed down from experienced teacher to new teachers. To be shown how to perform the experiments (and on many occasions have the explanation of the experiments directed to the teachers present within the lecture demonstration) gives confidence to teachers to practice and use some of the demonstration experiments with their own classes. Data and images used, and sometimes the whole PowerPoint themselves is often requested. For these reasons the PowerPoint for 'A Pollutant's Tale', its Spanish translation, the risk assessment and notes on the practicals is made available from the resources page of the Bristol ChemLabS outreach web site [50].

6. The benefits and limitations of all out-of-classroom learning

Despite the different types of visits and diverse outcomes, studies on science fieldtrips have revealed powerful findings [44, 51]. Their compatibility with the schools' science curriculum determines the educational effectiveness of the trip [45]. The UK's Department for Education and Skills (DfES) [52], has identified some of the benefits of out-of-classroom learning of any kind:

"*…by helping young people apply their knowledge across a range of challenges, learning outside the classroom builds bridges between theory and reality, schools and communities, young people and their futures. Quality learning experiences in 'real' situations have the capacity to raise achievement across a range of subjects [including science] and to develop better personal and social skills*".

Out-of-classroom learning, according to Braund & Reiss [53] is crucial to create motivation and fundamental to the understating of learning, which they describe as:

"*…when people visit or are taught in places that explain science in new and exciting ways, they frequently seem to be more enthused. There is, we believe, something about the contexts and places that brings about change through increasing the desire in people to find out and understand more*".

Similarly, a study made by Smart & Hutchings [54] as part of an evaluation of the Royal Institution's Science for School Programme indicates that almost all the teachers' responses emphasize the benefits of out-of-school learning in terms of its ability to motivate, inspire and enthuse students (7-18 years). 'Practical hands-on experience', which is part of some lectures, and 'watching demonstrations that could not normally be done in the classroom context' were perceived as the most valued activities by the teachers, which helped in the development of authentic science *(ibid)*. In addition, other benefits include: the ability to access an '*expert*' in science; the broadening of horizons; the provision of scientific role models for students; and the improvement of the development and integration of concepts have been observed by the authors.

Meanwhile, O'Donnell *et al's* study [56] indicates that about 92% of the Headteachers identified a range of benefits of out-of-classroom learning, which include: broadening students' experiences, a positive impact on students' attitudes and values; enhanced students' communication and social skills; and improves student behaviour and motivation. Moreover, fieldtrip studies to museums, reveal the lasting impact on students, in both cognitive and sociocultural contexts [47]. However, such positive impact would not be achieved without adequate planning and the delineation of goals, without which visits may be a wasted endeavour.

This leads to the identification of some of the limitations or barriers of bringing students for fieldtrips to any venue. Barker *et al* [57] indicates that there are still some who have concerns about the decline of the quality of learning outside of the classroom, despite the broad spectrum of benefits previously described. Such decline has been attributed to heath and safety issues and lack of confidence among teachers [44]. Lack of funding; time and resources to deliver such provision are also an issue. Similarly, teachers' limited knowledge of the provision of learning opportunities or programmes of out-of-classroom learning sometimes impeded their effort to bring their students for the visit [54]. In addition, they revealed that the difficulties in timetabling visits; travel costs and transport arrangements; and health and safety management hindered teachers' ability to organise out-of-classroom learning to some extent *(ibid).*

Michie's 1995 study [55] recognizes the role of pre-visit preparation between the field trip venue and the school itself. He indicates that despite the teachers' acknowledgement of the invaluable learning experiences for their students, limitations such as lack of support from school administration and lack of time for the preparation of relevant materials for the fieldtrip were a significant hindrance. O'Donnell *et al's* study [56] identified that one of the major challenges for the future development of out-of-classroom learning would be the amount of paperwork and administrative preparations such as the intensive risk assessment procedures required by the Local Education Authorities (LEAs), which inevitably adds to the difficulties of bringing students to out-of-classroom learning events. Presentations of 'A Pollutant's Tale' lecture demonstration are not limited to delivery in the home university lecture theatres. It was designed as a mobile lecture demonstration that may be delivered in schools up to four times per day [58]. This removes much of the burden of paperwork from the schools. It does not remove the need for a risk assessment for the lecture demonstration which can be sent to the schools in advance. Moreover a total of around a thousand students per day can be engaged in a suitable auditorium. With suitably experienced presenters the content of, and the language used within, the lecture demonstration can be adjusted appropriately. Having a School Teacher Fellow on the outreach team makes this relatively easy to do [4].

"We have just had someone from the Chemistry Department at the University of Bristol - Mr Harrison… He (also) did some experiments with carbon dioxide and liquid nitrogen, eggs, flowers, gloves, rubber tubing etc. which have converted the whole of KS2 - 240 children in half an hour! - including all of the "uncool to learn" crew. We are now changing our curriculum to include more of such activities! Schools need lots more of the same. It was wonderful to see the children so motivated." Headteacher of a Bristol inner city primary school, UK.

The Pollutant's Tale lecture demonstration has gone through a range of subtle changes over the past three to four years. Whilst the list of all demos in the full performance has stayed the same, the number performed is adapted according to the audience's age or experience. However, the underlying atmospheric science presented has changed slowly over time, as feedback has been assimilated. For example, the lecture for older students now contains a larger section on how we can combat rising levels of greenhouse gases and a longer section on the greenhouse effect itself and rarely includes metal chemistry occurring in the mesosphere. It is an important but often neglected fact that the reflective cycle is an important component to improving the effectiveness of a lecture demonstration. The value of good constructive feedback should not be overlooked either.

7. Summary

Effective lecture demonstrations are not magic shows but teaching and learning opportunities that can both enthuse and excite students and reinforce or support the work of the chemistry teachers. A Pollutant's Tale was created by consideration of the chemistry of climate change required at each level within the secondary curriculum. The primary version concentrates on the chemistry of the atmosphere but emphasises the difference between chemical and physical change especially changes of state.

There are only a handful of studies in the literature to investigate the potential use and effectiveness of cryogenics-based type of demonstrations. Research has shown the impact of practical work on students' learning and attitude. The more high quality lecture demonstration that can be performed the better.

Acknowledgements

We thank Bristol ChemLabS for support throughout this study and for the following under whose auspices various elements of this work was carried out; AimHigher, Royal Society of Chemistry, Royal Meteorological Society, Higher Education Academy, Triple Science Network and the Institute of Physics. Dudley Shallcross thanks the HEA for a National Teaching Fellowship.

Literature

[1] WHITE, R.T. (1988). *Learning Science*. Oxford: Basil Blackwell, p 186.

[2] TAYLOR,C. (1988). *The Art and Science of Lecture Demonstration*. New York: Taylor & Francis Group, pp1-2.

[3] http://www.chemlabs.bristol.ac.uk/outreach/A_Pollutant_s_Tale.html (accessed July 2010).

[4] SHALLCROSS D. E. & HARRISON T.G. (2007). A secondary School Teacher Fellow within a university chemistry department: the answer to problems of recruitment and transition from secondary school to University and subsequent retention? *Chemistry Education Research and Practice*, **8** (1), 101-104.

[5] SHALLCROSS, D. & HARRISON, T. (2008). 'Practical demonstrations to augment climate change lessons', Science in School, 10, 2008, pp 46-40 also available at http://www.scienceinschool.org/2008/issue10/climate (accessed July 2010).

[6] PIAGET, J. (1964). Development and Learning. *J. Res. In Sci. Teaching*, **2(3)**, 176-186.

[7] PIAGET, J. (1972). Intellectual evolutions from adolescence to adulthood. *Human Development,* **15 (1)**, 1.

[8] VYGOTSKY, L.S. (1967). Play and its role in mental development of a child. *Soviet Psychology-USSR*, **5 (3),** 6.

[9] SYLWESTER, R. (1986). Synthesis of research on brain plasticity: the classroom environment and curriculum enrichment. *Educational Leadership*, 90-93.

[10] WOLFE, P., & BRANDT, R. (1998). What do we know from brain research, *Educational Leadership*, 56(3), 8-13.

[11] LEFRANCOIS, G.R. (2000). *Psychology for teaching*. Belmont, CA: Wadsworth.

[12] ROADRUCK, M.D. (1993). Chemical demonstrations. *Journal of Chemical Education*. 70(12), 1025-1028.

[13] EGGEN, P., & KAUCHAK, D. (1999). *Educational psychology: windows on classroom* (4th Ed.). New Jersey: Merrill.

[14] BROWN, J.S., COLLINS, A., & DUGUID, P. (1989). Situated cognition and the culture of learning. *Educational Researcher*, 18(1), 32-42.

[15] GREENO, J.G. (1989). A perspective on thinking. *American Psychologist*, 44(2), 134-141.

[16] GREENO, J.G. (1998). The situativity of knowing, learning and research. *American Psychologist*, 53, 5-26.

[17] LAVE, J., & WENGER, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge, UK: Cambridge University Press.

[18] LUEHMANN, A.L., & MARKOWITZ, D. (2007). Science teachers' perceived benefits of an out-of-school enrichment programme: Identity needs and university affordances. *International Journal of Science Education*, 29(9), pp1133-1161.

[19] BEASLEY, W. (1982). Teacher demonstrations: the effect on the student involvement. *Journal of Chemical Education,* 59(9), 789-790.

[20] BUNCICK, M.C., BETTS, P.G., & HORGAN, D.D. (2001). Using demonstrations as a contextual road map: enhancing course continuity and promoting active engagement in introductory college physics. *International Journal of Science Education*, 23(1), 1237-1255.

[21] BOGEN, G.K. (1963). An appraisal of the travelling science demonstration lecture programme in Oregon and its effectiveness as an agent for in-service education [Abstract]. Accessed from *ERIC Database*, ED019584 on 15 July 2008.

[22] GARDNER M. (1978). *Aha! Insight*. New York: Scientific American.

[23] GERBER, B.L., CAVALLO, A.M.L., & MAREK, E.A. (2001). Relationships among informal learning environment, teaching procedure and scientific reasoning ability. *International Journal of Science Education,* 23(5), 535-549.

[24] MORRIS, C. (1990). Importing 'hands-on' science into schools: the Light Works Van Programme. *Physics Education*, 25, 263-265.

[25] CSIKSZENTMIHALYI, M. (1990). *Flow: The physiology of optimal experience*. New York: Harper Perennial.

[26] LOPEZ-GARRIGA, J., MUNOZ-SOLA, Y., TORRES., V., ECHEVARRIA, Y., NAZARIO, W., JESUS-BONILLA, W. & CAMACHO-ZAPATA, R. (1997). Science on wheels: A coherent link between educational perspectives. *Journal of Chemical Education*, 74(11), 1346-1349.

[27] LEE, N.E., & SCHREIBER, K.G. (1999), The chemistry outreach program: women undergraduates presenting chemistry to middle school students. *Journal of Chemical Education*, 76(7), 917-918.

[28] BRUCE, B.C., WEISMANN, M., & NOVAK, M. (1997). Science education outreach: Physics demonstrations, lectures and workshops. *The Journal of Illinois Science Teachers Association*, 23(2), 8-12.

[29] CALEON, I.S., & SUBRAMANIAM, R. (2005). The impact of a cryogenics-based enrichment programme on attitude towards science and the learning of science concepts. *International Journal of Science Education*, 27(6), 679-704.

[30] CALEON, I.S., & SUBRAMANIAM, R. (2007). Augmenting learning in an out-of-school context: The cognitive and affective impact of two cryogenics-based enrichment programmes on upper primary students. *Research in Science Education*, 37, 333-351.

[31] FALK, J.H., & BALLING, J.D. (1982). The field trip milieu: Learning and behaviour as a function of contextual events. *Journal of Educational Research*, 76(1), 22-28.

[32] JARVIS, T., & PELL, A. (2002). Effect of the Challenger experience on elementary children's attitudes to science. *Journal of Research in Science Teaching*, 39(10), 979-1000.

[33] LISOWSKI, M. (1987). The effect of field-based learning experiences on students' understanding of selected ecological concepts. *ERIC Database*, ED281768 (Accessed on 17 July 2008)

[34] SHEPARDSON, D.P., MOJE, E.B., & KENNARD-MCCLELLAND, A.M. (1994). The impact of a science demonstration on children's understanding of air pressure. *Journal of Research in Science Teaching*, 31(3), 243-258.

[35] ROTH, W.M., MCROBBIE, C.J., LUCAS, K.B., & BOUTONNE, S. (1997). Why may students fail to learn from demonstrations? A social practice perspective on learning in Physics. *Journal of Research in Science Teaching,* 34(5), 509-533.

[36] FORGAN, S. (1985). Faraday – from servant to savant: the institutional context. In D.Gooding and F.A.J.L. James (Eds.), *Faraday Rediscovered*. Basingstoke: Macmillan Press, pp51-68.

[37] STOCKLMAYER, S., & GILBERT, J.K. (2005). Informal Chemical Education. In Gilbert, J.K. *Constructing worlds through science education. The selected works of John K. Gilbert* (pp157-172*)*. London: Routledge Taylor & Francis Group.

[38] TUAH, J. (2008). Investigating Bristol ChemLabS outreach: How does a Science Lecture Demonstration an a practical science workshop impact upon Secondary School Students' Attitudes towards Science and Learning of Science Concepts?, Masters Degree Thesis, University of Bristol.

[39] DEWITT, J., & OSBORNE, J. (2007). Supporting teachers on science-focused school trips: towards an integrated framework or theory and practice. *International Journal of Science Education*, 29(6), 685-710.

[40] KISIEL, J. (2005). Understanding elementary teacher motivations for science fieldtrips. *Science Education*, 89(6), 936-955.

[41] COX-PETERSEN, A.M., & PFAFFINGER, J.A. (1998). Teacher preparation and teacher-student interactions at a discovery center or natural history. *Journal of Elementary Science Education*, 10(2), 20-35.

[42] GRIFFIN, J., & SYMINGTON, D. (1997). Moving from task-oriented to learning-oriented strategies on school excursions to museums. *Science Education*, 81(6), 763-779.

[43] RENNIE, L.J., & MCCLAFFERTY, T.P. (2001). Visiting a science center or museum? Make it a real educational experience!. In Errington, S., Stockmayer, S.M., & Honeyman, B. (Eds.), *Using museums to popularise science and technology* (pp73-76). London: Commonwealth Secretariat

[44] RICKINSON, M., DILLON, J., TEAMEY, K., MORRIS, M., CHOI,M.Y., SANDERS,D.,D. & BENEFIELD, P. (2004). A review of research on outdoor learning: Executive summary (Accessed on 5 May 2008, at URL: http://www.nfer.ac.uk/research-areas/pims-data/summaries/fsr-a-research-review-of-outdoor-learning.cfm.

[45] RENNIE, L.J. (2007). Learning science outside of school. In Abell, S.K., & Lederman, N.G. (Eds.). *Handbook of Research on Science Education*, (pp125-16). Mahwah: Lawrence

[46] ANDERSON, D. (1999). The development of science concepts emergent from science museum and post-visit activity experiences: Students' construction of knowledge. Unpublished doctor of philosophy thesis, Queensland University of Technology, Brisbane, Australia.

[47] FALK, J.H. & DIERKING, L.D. (2000). *Learning from museums: Visitor experiences and the making meaning*. Walnut Creek. CA: AltaMira Press.

[48] ORION, N., & HOFSTEIN, A. (1994). Factors that influence learning during a scientific fieldtrip in a natural environment. *Journal of Research in Science Teaching*, 31(10), 1097-1119.

[49] ANDERSON, D., KISIEL, J., & STORKSDIECK, M. (2006). Understanding teachers' perspectives on field trips: Discovering common ground in three countries. *Curator*, 49(3), 365-386.

[50] http://www.chemlabs.bris.ac.uk/outreach/resources/ (last accessed July 2010)

[51] GRIFFIN, J. (2004). Research on students and museums: Looking more closely at the students in school groups. *Science Education,88(Suppl.1),* S59-S70.

[52] DfES (2006). *Learning outside the classroom MANIFESTO*, HMSO. Nottingham: Department of Education and Skills, p4.

[53] BRAUND, M., & REISS, M. (2004). *Learning science outside the classroom*. London: Routledge Falmer, p5.

[54] SMART, S. & HUTCHINGS, M. (2007). *The 'wow' factor: teachers' expectations of, attitudes towards and experiences of pupils learning science outside the classroom*. Paper presented at the

British Educational Research Association (BERA) Annual Conference, Institute of Education, University of London.

[55] MICHIE, M. (1995) Evaluating teachers' perceptions of programs at a field center. *Science Teachers Association of the Northern Territory Journal*, 15, 82-92.

[56] O'DONNELL, L., MORRIS, M. & WILSON, R. (2006*) Education Outside the Classroom: An assessment of Activity and Practice in Schools and Local Authorities*. National Foundation for Education Research (NFER), Research Report 803, Nottingham: Department of Education and Skills.

[57] BARKER, S., SLINGSBY, D. & TILLING, S. (2002). Teaching Biology outside the classroom: is it heading for extinction? A report on Biology Fieldwork in the 14-19 Curriculum (FSC Occasional Publication 72). Shrewsbury: Field Studies Council.

[58] HARRISON T.G., HUGHES, L. & AND SHALLCROSS D.E. (2008), 'Jersey Schools Science Week: An outreach case study', *New Directions in the Teaching of Physical Sciences, Published by the Higher Education Academy Physical Sciences Centre*, **4**, 30-33.