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SCIENCE OUTREACH AND SCIENCE EDUCATION: THE ANALYSIS OF DILEMMAS FACED TO PROMOTE THE CREATION OF THE THIRD SPACE

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Abstract: To achieve economical growth, countries such as Ireland need to continue to invest in scientific enterprise, which necessitates having more students choose and follow scientific careers. Current literature and policies point out that science education needs structural and methodological changes to respond to this objective of challenging our youth to choose science. This has resulted in an increasing call for science outreach programs. Nevertheless, these programs have been classified as still sporadic and incoherent. To achieve their objectives and potential it is argued that they need to be further integrated within the formal sector, thus creating a third space in science education. This study will address this issue by focusing in the final two years of the primary level science education. Teachers and science outreach practitioners will be faced with methodological issues for fostering students' interest in science. This research method will be applied in order to investigate and design an effective model(s) of science outreach. It also aims to comprehend where the issues and tensions lie between science outreach and science education and how they affect the potential for the creation of partnerships between schools and outreach providers.

Keywords: science education, science outreach, third space, dilemmas, inquiry based learning.

1. Introduction

Worldwide, science has become economically very important. The idea of a scientific society that needs an increasing number of science graduates in the workforce is dominant (Osborne & Dillon, 2010). The European Union and different EU countries, such as Ireland, stress that science and technology graduates are fundamental for economical growth (European Commission, 2007; Ireland. Department for Jobs, 2011). Nevertheless, reports show that, in Ireland the number of graduates in science, technology and mathematics' is not achieving the desired targets (European Commission, 2011). Ireland is not an isolated case, and a trend of diminishing interest in science has been identified

in other countries (OECD, 2006 ; Tytler, 2008). Therefore, policy documents of several countries state the need to change the way science is taught in schools and for further action to be taken to encourage students to pursue science degrees (DETE, 2009 ; European Commission, 2011 ; Tytler, 2008). Recent reports highlight the potential that informal science programs designed predominantly by Universities and other organizations, e.g. Industry, for primary and second level students (henceforth denominated as science outreach programs) can have, in improving student engagement in science and also as a direct vehicle in assisting science education in the classroom (Luehmann, 2009 ; Luehmann & Markowitz, 2007 ; Stocklmayer, Rennie, & Gilbert, 2010). For that, it is deemed that a stronger partnership between schools and science outreach providers is needed (European Commission, 2007; Stocklmayer, Rennie, & Gilbert., 2010). The value of the partnership between schools and science outreach providers cannot be overemphasized, and as such forms the basis of this research. This research aims to analyze the critical reflections and proposed solutions from both classroom teachers and science outreach practitioners, in response to dilemmatic cases that they face at primary level, when developing inquiry based learning activities.

2. Review of the Literature

Changing science education, to make it more engaging and meaningful for students is not a new objective. Schwab (1965) was one of the first researchers to design a model for science education that favored inquiry based learning instead of a transmissive model of teaching. Since then, inquiry based learning has been exhaustively researched and different models have been developed (Bell et al., 2010; Hmelo-Silver et al., 2007). The theoretical basis for inquiry based learning comes from theories of constructivist learning (Matthews, 2002). Although constructivist learning theory is often differentiated in terms of cognitive constructivism (Wadsworth, 1978), and social constructivism (Vygotskij *et al.*, 1986), the author has chosen to use the combination of both, as they each contribute to inquiry based learning (Windschitl, 2002). The constructivist theory of learning (Driver, Asoko, Leach, Mortimer, & Scott, 1994; Shepard, 2000; Tobin & Tippins, 1993) discussed in this paper uses a synthesis of cognitive and social constructivist perspectives, claiming that knowledge is personally constructed and socially mediated by the learner.

In recent years, with the decline in the number of students choosing to study science at university level (OECD, 2006) there has been a renewed call for change in science education (DETE, 2009; European Commission, 2011; Tytler, 2008). The European Commission report (2007) acknowledges that the

focus of European level initiatives should be directed towards changing science teaching from deductive to inquiry based learning methods. Accordingly, science curricula and standards in several countries (National Curriculum, 2009, National Research Council, 2011) including Ireland (DES, 1999) reflect an inquiry based learning philosophy. Nevertheless, this method has yet to become popular in terms of teaching practices in Ireland, where teachers continue to rely on the transmissive method of teaching (OECD, 2010; McCoy, Smyth, & Banks, 2012). The lack of support for science teaching is even more pressing at primary level. The majority of primary level teachers in Ireland do not have a background in science (Killeavy, 2001). Furthermore, the science curriculum at primary level is less than ten years in existence, with a large number of the practicing teachers not having completed professional development in science education (Varley, Murphy & Órlaith, 2008).

The difficulty in long term change towards inquiry based learning is not an isolated Irish problem and it is well reported in the literature (Blanchard et al., 2010 ; Stocklmayer, Rennie, & Gilbert., 2010) as are primary teacher's challenges and issues in implementing meaningful inquiry learning (Appleton, 2006 ; Brand & Moore, 2011 ; van Aalderen-Smeets et al., 2012 ; Yoon & Kim, 2009).

The calls for change in science education combined with reports that state the need to have more students following science has made an impact in universities and science related organizations. Universities are now aware that they need to do more to attract students to science (June, 2009; Stocklmayer, Rennie, & Gilbert., 2010) Therefore, the number of science outreach programs for primary and second level students is increasing, with a great number of them focusing on hands-on inquiry based learning activities (Crane & National Science, 1994 ; Jeffers *et al.*, 2004). These science outreach programs, specifically directed at primary and second level students, have the potential to integrate more inquiry based learning in the science classroom and ideally impact an increased interest in science (European Commission, 2007; Stocklmayer, Rennie, & Gilbert., 2010). The European Commission Report (2007) advocates that science outreach can serve as a catalyst to accelerate the pace of change in science education. Stocklmayer, Rennie, & Gilbert (2010) argue that science outreach can create a third space in science education. Building on the work of Moje et al (2001) the third space is defined as one in which the formal school science (first space) and these informal programs (second space) merge; a programme that deliberately connects the curriculum content with the reality of science, a collaborative design that meets the needs of both parties (educator and outreach), who both desire to enhance students science education. The metaphor of a third space comes as an advancement of the building bridges perspective as the following quote explains:

Building bridges is a necessary part of what makes third space because it helps learners see connections, as well as contradictions, between the ways they know the world and the ways others know the world. ... Unlike the bridge perspective, however, a third space focused on cultural, social and epistemological change ... is one in which everyday resources are integrated with disciplinary learning. (Moje et al 2001, p. 44)

In its complete form, the third space means that science outreach would be more than a once off or occasional experience that happens in the classroom; it would be a reality integrated in the everyday working of the formal sector of science education.

In spite of the positive effects argued for science outreach and the potential that the idealized third space can have in the enhancement of student's science education, a variety of issues have been identified. A recurrent one is the fact that researchers and outreach officers that develop these science outreach programs are often not aware of what happens in a classroom or of curriculum content/sequence, and therefore see themselves as not having the skills or professional development to deal with the students (Stocklmayer, Rennie, & Gilbert, 2010; Thiry, Laursen, & Hunter, 2008). A second issue is that these science outreach programs are still sporadic and incoherent depending on an enthusiastic science outreach officer or volunteer scientists (Stocklmayer, Rennie, & Gilbert 2010; Tytler, 2008). This study examines these issues, focusing on dilemmatic cases faced by science outreach volunteers and primary level teachers when developing inquiry based curricular activities, as it is argued that in order to contribute adequately to the creation of a third space, science outreach providers need to further develop connections with the curricula and schools.

3. Research rationale

Although there are concerns regarding student engagement and teaching methods, at both primary and secondary level, the author chose to focus on primary level for three reasons. Firstly, the literature shows that by the end of primary level education, most pupils have already ruled out science as a future career choice (van Aalderen-Smeets et al., 2012). This is, therefore, considered a core time to motivate students for science (European Commission, 2007). The second reason has to do with teacher training/professional development in science education, or lack of, creating a valued opportunity for science outreach to intervene. And finally, there is already a great number of science outreach programs designed specifically to target the primary level students in Ireland (Davison *et al*, 2008), and therefore suggested changes from this research could result in a substantial impact.

The research questions that will be investigated are as follows:

- What conceptual and pedagogical challenges do teachers and science outreach practitioners face in the primary level classroom when developing an inquiry learning, hands-on curricular approach?
- What are the different solutions primary level teachers and science outreach practitioners offer to address the identified challenges?
- What is the reasoning and belief system behind the various solutions presented?

3.1 Dilemma rationale

As it was mentioned in the section 1, this research aims to analyze teachers and science outreach practitioners' solutions and reflective thinking in response to challenges they face in the primary level science classroom, when developing inquiry-based learning activities. The challenges faced by teachers when trying to implement constructivist methodologies in education is not unique to science teachers. Windschitl (2002) explains these challenges through a dilemmatic framework. The author defined four different levels of dilemmatic categories: conceptual, pedagogical, cultural and political (figure 1)

<i>Dilemmatic category</i>	<i>Dilemma rationale</i>
<i>Conceptual dilemmas</i>	<i>Grasping the underpinnings of cognitive and social constructivism; reconciling learning environment. current beliefs about pedagogy with the epistemological orientations necessary to support a constructivist</i>
<i>Pedagogical dilemmas</i>	<i>Honoring students' attempts to think for themselves while remaining faithful to accepted disciplinary ideas; developing deeper knowledge of subject matter; mastering the art of facilitation; managing new kinds of discourse and collaborative work in the classroom</i>
<i>Cultural dilemmas</i>	<i>Becoming conscious of the culture of one's own classroom; questioning assumptions about what kinds of activities should be valued; taking advantage of experiences, discourse patterns, and local knowledge of students with varied cultural backgrounds; managing the collective transformation of students' beliefs and practices in accordance with constructivist norms.</i>
<i>Political dilemmas</i>	<i>Confronting issues of accountability with various stakeholders in the schoolroom munity; negotiating with key others the authority and support to teach for understanding.</i>

Figure 1 –Constructivist dilemmatic categories - adapted from Windschitl (2002)

The methodological focus of this research builds upon Windschitl conceptualizations, particularly on the pedagogical and conceptual categories.

The reasons for the selection of these categories and the exclusion of the cultural and political ones are now presented.

Science outreach practitioners usually develop their work within a school for a limited amount of time (Jeffers *et al.*, 2004). They are not present, and possibly cannot be expected to be, in a particular school every week or even every month. Therefore, their role in the cultural dilemmas is an indirect one. Science outreach practitioners do not normally have a direct active role in the issues that arise in the school community whilst it reorganizes itself towards a constructivist science education, i.e. cultural dilemmatic types.

The reasoning made for the cultural category explains as well why political dilemmas are out of the direct scope of science outreach practitioners. One of the argued advantages of the informal science experiences, which outreach offers to students, is that it does not suffer from the type of pressures that science education does (Stocklmayer, Rennie, & Gilbert, 2010). An example of a pressure of this type is the objective of minimum competency in tests that push teachers to direct methods of instruction (Windschitl, 2002). These types of pressures do not influence directly the informal activities of science outreach. Once again, the role of outreach practices is indirect in these specific issues.

For the cultural and political dilemmatic categories, it is stated that outreach does not have a direct role in its resolution, albeit the relevant indirect influences. The indirect influences exist because these categories should be viewed in an ecological way (Windschitl, 2002). The ecological view acknowledges that the four dilemmatic types are interconnected and therefore, although outreach work is more directly related to pedagogical and conceptual dilemmatic situations, the work developed by practitioners will obviously influence the cultural and political issues lived in school.

After stating the two categories that are not directly relevant to outreach, it is necessary to understand why the other two are relevant to both teachers and science outreach practitioners (conceptual and pedagogical). The reasoning for this argument comes directly from the specific work developed by science outreach practitioners. Science outreach origins and practices direct us to constructivism: hands on experiences for active engagement; inquiry learning experiences; use of artifacts for open construction (Crane & National Science, 1994 ; Jeffers *et al.*, 2004). Therefore, conceptual dilemmas, dilemmas that deal with the grasping of the concepts that guide constructivism, are of direct relevance to science outreach practitioners.

Pedagogical dilemmas are the ones which teachers face when designing the curriculum and learning experiences that constructivism demands. Curricular design is usually already out of the scope of a science outreach initiative (Crane & National Science, 1994 ; Jeffers *et al.*, 2004), however, designing learning experiences that foster constructivist objectives are the

bread and butter of science outreach practitioners. A review of the literature reveals innumerable examples of science outreach activities that enter the classroom with clear constructivist objectives connected with inquiry based learning activities (Crane & National Science, 1994). Accordingly, these types of dilemmas are relevant to both teachers and outreach practitioners.

3.2 Dialectical nature of the research

The dilemma framework is used in this research in its etymological dialectical origin, a choice between two opposite alternatives, as another corner stone of this research is dialectics: the methodology followed is dialectical in its nature. Therefore, the methodology used in this research builds upon other studies that focused on having teachers illustrate and explain dilemmas they face in practice (Yoon & Kim, 2009); or on the analysis of selected dilemmas throughout a methods course (Tippins, Nichols & Dana, 1999). In the case of this research, the methodology involves the design and presentation of contextualized and specific dilemmatic cases to both teachers and outreach practitioners. Each case will follow the classic definition of dilemma, in which two conclusive, opposing arguments will be presented (Tillema, & Kremer-Hayon, 2002). Through an interview process, the choices made and reasoning behind them will be pursued.

The use of dilemmas in such a way, and the method of confronting practitioners with them, stems from the dialectical approach followed. This research aims to unravel the tensions and contradictions faced by practitioners, when having to make choices during their practice in science education and outreach. The dialectical view presented is one which acknowledges that new knowledge is a constructed synthesis which resolves the inevitable contradictions arising during the course of interactions between individuals and their surrounding environment (David, 1982, p.375). The dialectical use of dilemmas has the potential of producing contextualized reflection (Yoon & Kim, 2009) as it can lead the research participants to interrogate their own beliefs and question institutional routines (Windschitl, 2002).

The conceptual dilemmas (figure 2) are grounded in core constructivist concepts and its epistemological dialectical oppositions. The pedagogical dilemmas (figure 2) were selected by analyzing the Irish primary science curriculum (DES, 1999).

Conceptual dilemmas	Pedagogical dilemmas
Autonomy ↔ Dependency (McRobbie and Tobin, 1997, Davis, 2003)	Open inquiry ↔ Structured Inquiry Activity selected to be presented according to both dialectical poles: - The Colored Plant (DPS, 2012) (from the curricular strand investigate factors that affect plant growth)
Deduction ↔ Induction (Reid, 2011; Kirschner et al., 2006)	Observation and identification for deduction ↔ Experimentation through manipulation for induction Activity selected to be presented according to both dialectical poles: - Wag: the dog(DPS, 2012) (from the curricular strand explore how levers may be used to help lift different objects: design and make a toy using a lever)
Creativity ↔ Guidance (Ronald A, 2007; Newton and Newton 2009)	Open construction of object ↔ Specific construction of object Activity selected to be presented according to both dialectical poles: - Build a magnetic car (DPS, 2012) (from the curricular strand Learn that magnets can push or pull different materials)

Figure 2 –Conceptual and pedagogical dilemmas selected for the study

The method used for the conceptual dilemmas consists in having the research participants analysing different views of the opposite concepts. This method is congruent with previous studies which used claims from researchers to evaluate research participants' beliefs regarding inquiry based learning (Bencze & Bowen, 2009).

The concepts presented in the conceptual dilemmas also guide the pedagogical dilemmas, the dilemmas that relate with specific activities selected by the Irish curriculum. As the model favored by the Irish curriculum and outreach practices is inquiry learning (DES, 1999), inquiry learning is highlighted in these dilemmas. The use of the curriculum to generate research instruments to be presented to teachers has strong support in the science education literature; it is argued that notions of learning relate to practice more closely when they are assessed at the specific level of a curriculum (Harwood, Christine, 2006, Newton & Newton, 2009). Adding to this, the Irish primary science curriculum offers various possibilities, in terms of practices, for the

teachers. The curriculum can be reconstructed in accordance to different significations and beliefs (DES, 1999). And there is strong evidence that shows that this happens. Previous research focusing on curricula has concluded that teachers often reconstruct it in their practice (Pintó, 2005). The topics and activities suggested by the curriculum can then be presented according to different conceptualizations of science education. The curriculum can be followed according to either of the dialectical poles of the conceptual dilemmas, or somewhere in the continuum between them. Therefore, the method selected to present the pedagogical dilemmas consists of having the research participants examining curricular activities designed according to the opposing dialectical concepts (figure 2).

4. Analysis of findings

As this is still a work in progress, at this moment there are still no findings to be presented and/or analyzed. Nevertheless, it can be advanced that the analysis will follow a mixed methods nature, in which qualitative and quantitative methods of analysis will be employed, congruent with the rationale of the study and of previous research work that followed equivalent methodology (Harwood, Hansen and Lothar, 2006).

5. Conclusions

As science outreach is becoming a relevant and valued presence in primary schools (European Commission, 2007), this study aims to further enhance these practices through the analysis of these dilemmatic cases from the perspective of both teachers and outreach practitioners. Two main reasons justify this. First, science outreach practitioners can offer valuable new views on dilemmas in science education (Thiry, Laursen, & Hunter, 2008). Second, by identifying and understanding these dilemmas, science outreach practitioners can incorporate new insights in the development of their programmes to promote science to youngsters (Stocklmayer, Rennie, & Gilbert., 2010). These insights can potentially assist in the effective creation of the aforementioned third space in the context of primary level science education and science outreach in Ireland, enabling the formation of a collaborative community of elementary science education.

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POPULARIZACIJA ZNANOSTI I PRIRODOSLOVNO OBRAZOVANJE: ANALIZA IZAZOVA U PROCESU PROMICANJA STVARANJA DODATNOG PROSTORA

Sažetak Kako bi ostvarile gospodarski rast, države se oslanjaju na znanstvena istraživanja, za što je potreban sve veći broj znanstvenika, što za sobom povlači potrebu da se više studenata odlučuje za znanstvenu karijeru. Literatura i postojeća praksa sugeriraju kako su prirodoslovnom obrazovanju potrebne strukturalne i metodološke prilagodbe kojima bi se odgovorilo na zahtjev za mladim znanstvenicima. S ciljem povećanja interesa za znanost i unaprjeđivanje poučavanja u školi organiziraju se programi popularizacije znanosti. Ti su programi nažalost još uvijek sporadični i nekoherentni. Smatra se da je potrebna njihova daljnja integracija u formalno obrazovanje kako bi se ostvarili njihovi ciljevi i potencijal. Time bi se stvorio tzv. treći prostor djelovanja (eng. third space) u prirodoslovnom obrazovanju,