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Dialectic dividends: Fostering hybridity of new pedagogical practices and partnerships in science education and outreach

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Abstract

Internationally, science literacy has become socially and economically very important. Many European countries, including Ireland, stress that science and technology graduates are fundamental for economic growth. Nevertheless, there is a recognized trend of diminishing interest in science by students. In response, there has been a call to change the way science is taught in schools which focuses on inquiry methods rooted in constructivism, and for further encouragement of students to pursue science degrees. Specifically at primary level, there is a recurrent view that teachers lack the confidence and pedagogical knowledge to teach science by inquiry. Universities and other organizations have responded by developing science outreach programmes to improve student engagement in science, and to promote inquiry in the classroom. Given this context, there is a necessity for research in this area to ascertain if this new relationship between outreach and education is worthwhile, and therefore the analysis and comparison of both fields warranted.

This study examines and compares primary teachers’ and outreach practitioners’ understanding and perceptions of constructivist science pedagogy in an effort to understand the potential of the teacher-outreach symbiotic partnership. A mixed-methods approach was employed. The Constructivist Learning Environment Survey was completed by 149 teachers and 89 outreach practitioners and semi-structured interviews, presenting constructivist dilemmatic cases were carried out with 31 teachers and 30 outreach practitioners.

The results obtained contradict the view that teachers do not have a strong science pedagogical sense, and are resistant to constructivist approaches. Both teachers and outreach providers revealed favourable views in relation to constructivism, despite recognizing barriers to its implementation. These results move the mind-set away from one that assumes the teacher lacks this pedagogical knowledge towards one that supports the teacher-outreach symbiotic partnership and the realisation of the hybrid role of each participants. The results obtained have also revealed an important gatekeeper dynamic in outreach access to schools. The study ends with implications and recommendations derived from these conclusions.
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Declaration

I hereby certify that this material, which I now submit for assessment on the programme of study leading to the award of Doctor of Philosophy, is entirely my own work and has not been taken from the work of others save and to the extent that such work has been cited and acknowledged within the text of my work.

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Signature of Candidate:

Date:
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List of Acronyms

AF - Academy Of Finland
ALLEA - the federation of All European Academies
CEIA – Cork Engineering and Industry Agency
CLES - Constructivist Learning Environment Survey
CORDIS - Community Research and Development Information Service
CSIRO - Commonwealth Scientific and Industrial Research Organisation
DES – Department of Education and Skills
DJEI - Department of Jobs, Enterprise and Innovation
DoD – Department of Defense
DPSM – Discover Primary Science and Maths
DSI – Debating Science Issues
INTO - Irish National Teachers’ Organisation
NASA - National Aeronautics and Space Administration
NCCA - National Council for Curriculum and Assessment
NUIG - National University of Ireland, Galway
NSF – National Science Foundation
OECD - Organisation for Economic Co-operation and Development
ReSciPE - Resources for Scientists in Partnership with Education
ROSE - The Relevance of Science Education
SFI – Science foundation Ireland
STEPS - Science, Technology and Engineering Programme for Schools
TALIS - Teaching and Learning International Survey
Papers and Conference Proceedings


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July 2012 European Science Education Research Association Summerschool participant

May 2012 Didactic Challenges International Conference, Croatia. Paper Presenter

Chapter One: Introduction
1.1. Introduction

In Ireland, promoting science in education and society is a key concern of the government and educational institutions (Davison et al., 2008; DETI, 2009; Regan, 2009). The concern of Irish policymakers is shared by governments worldwide. Governments, realising that science influences every aspect of modern life, aim to boost scientific capacity to promote economic growth and a well informed and empowered society. Traditionally, the target of efforts to enhance scientific capacity has been through school science education and carried out through curricular change and teacher training (Bell et al., 2009). Apart from the formal school experience, students have abundant opportunities to be involved with science. Examples of these opportunities are after school science programmes, open day visits to universities or science summer camps. According to Bell et al. (2009, p.1) “people of all backgrounds engage in activities that can support science learning in the course of their daily lives”. Efforts to provide informal opportunities to engage with science and integrate it with formal learning are comparatively new (Tressel, 1994). Therefore, the links to formal learning experiences are not usually planned or accounted for (Crane et al., 1994).

Nevertheless, in recent years, informal opportunities for young people to engage with science have increased in number (Holmegaard et al., 2014; Jeffers et al., 2004; Stocklmayer et al., 2010; Tan et al., 2013). This increase is in response to the recognised decline of interest in science by students and the consequent shortage of science graduates (European Commission, 2011; OECD, 2006; Osborne and Dillon, 2010; Regan and DeWitt, 2015). Informal learning activities are being recognized as a supplement to the formal learning of science (European Commission, 2007; NSF, 1998; Stocklmayer et al., 2010). Stocklmayer et al., (2010, p.26) asserts that “the informal education sector (...) is relatively free to assist in the provision of worthwhile education by means of which young people become actively engaged in learning about Science.”. The European Commission report (2007) stresses that informal opportunities can accelerate the pace of change in science education. This report specifically highlights the role of scientists and universities in providing these opportunities to strengthen the links between formal and informal science education. The case for involvement of universities and scientists is also put forward by the NSF (1998):

We cannot expect the task of science education to be the sole responsibility of (...) teachers while scientists and graduate students live only in their universities and laboratories. There is no group of people who should feel more responsible for science (...) education (...) than our scientists and scientists-to-be (para. 13).

In Ireland, the informal opportunities for students to engage with science are also increasing, reflecting this global trend. Specifically in the area of education, there has been a shift to meet the challenge of engaging young people in science. This shift led to the introduction of science as a subject in its own right within the Irish primary curriculum in 2003. Before that, there was a recognised “neglect of science in primary schools” (Varley et al., 2008, p. 15). To aid this integration of science in Irish primary schools, different institutions, particularly universities, introduced new informal science outreach programmes (SFI, 2014a). Due to the recent introduction of science at primary level and the existence of a great number of informal science outreach programmes, this study examines these programs in the context of primary level education in Ireland. The study is located between science outreach and science education at primary level in order to promote a more efficient collaboration between both areas and a more engaging science experience for students.
Informal programmes carried out by universities for primary and second level students are quite recent (Jeffers et al., 2004; Stocklmayer et al., 2010). Nevertheless, involvement of scientists with a wider audience has existed for a long time. It dates back to Galileo and ancient Greece and in more recent times to the very “propitious nineteenth century” (Carrada, 2006, p.10). Science communication and informal science education are the disciplines that traditionally examine the widening participation of the public with science (Bell, et al., 2009; Burns et al., 2003). This Chapter contextualises the recent informal programmes that aim to engage students in science within the disciplines that traditionally have examined the sharing of science in a wider context. First it discusses science communication and informal science education. The section ends with the definition of where this study is grounded: science outreach for primary and second level students.

1.2. A global view of science outreach: a practice influenced by science education, science communication and informal science education

This study explores the pedagogical approach within science outreach programmes carried out by universities in the context of primary level education in Ireland. Science outreach programmes are initiatives promoted predominantly by universities to engage students in science (Davison et al., 2008; Jeffers et al., 2004). Due to its recent emergence, the related literature is erratic, with science outreach entangled within different disciplines (Stocklmayer et al., 2010). More specifically, the literature of science outreach is influenced by science communication, informal science education and formal science education. The crux of this thesis is the relation between science outreach and formal science education at primary level. As such, Chapter two is dedicated to this analysis. This section focuses on the other disciplines that influence science outreach. It starts by discussing science communication and the two approaches that describe society’s relationship with science: public understanding of science and public engagement of science.

1.2.1 Science Communication

Science communication is a term that suffers from ambiguity. According to Burns et al. (2003) the term has been used as a synonym of public understanding of science, science literacy or scientific culture. To overcome this ambiguity, Burns et al., (2003) define science communication according to the personal responses to science it intends to produce, as seen in figure 1.1.

Figure 1.1 The vowel analogy to define science communication (Adapted from Burns et al., 2003)

<table>
<thead>
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<th>“Science communication may be defined as the use of appropriate skills, media, activities, and dialogue to produce one or more of the following personal responses to science (the vowel analogy):</th>
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<td>- Awareness, including familiarity with new aspects of Science;</td>
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<tr>
<td>- Enjoyment or other affective responses, e.g. appreciating Science as entertainment or art;</td>
</tr>
<tr>
<td>- Interest, as evidenced by voluntary involvement with Science or its communication;</td>
</tr>
<tr>
<td>- Opinions, the forming, reforming, or confirming of Science-related attitudes;</td>
</tr>
<tr>
<td>- Understanding of Science, its content, processes, and social factors.”</td>
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The vowel analogy highlights the complementary objectives of the field. It is a holistic definition in which the cumulative objective is to identify the public’s awareness, enjoyment, interest, opinions and understanding of science. Addressing one or more of the five objectives is, by itself, science communication, as the vowel analogy represents a “continuum of desirable personal reactions to science communication” (Burns et al., 2003, p.196). In the science communication literature there are two predominant approaches to produce these desirable personal reactions: public understanding of science and public engagement of science (Bell et al., 2009). They represent the two poles within the continuum of approaches to understand the publics’ relationship with science. The next two sections review these two approaches starting with public understanding of science.

1.2.1.1 Public Understanding of Science

Public understanding of science represents an approach to science communication which is concerned with the understanding of its contents, processes and societal implications. The House of Lords Science and Technology Committee (2000) report defined public understanding of science as:

...Understanding of scientific matters by non-experts (....) include(s) understanding of the nature of scientific methods (...) awareness of current scientific advances and their implications. Public understanding of Science has become a shorthand term for all forms of outreach (in the UK) by the scientific community, or by others on their behalf (e.g., Science writers, museums, event organizers), to the public at large, aimed at improving that understanding (p. xx).

As stated in the previous section, the terms public understanding of science and science communication are used interchangeably in the literature (Burns et al., 2003). According to the definitions presented for science communication and public understanding of science, this is erroneous. Public understanding of science is part of science communication. Nevertheless, science communication is more than understanding. Science communication involves the entire personal responses previously presented: awareness, enjoyment, interest, opinions and understanding. Understanding is just one of the personal responses science communication purposes to produce in the public.

Wynne (1989) was the first to criticize science communication activities that followed the public understanding of science approach. Wynne (1989, p. 38) referred to it as the ‘deficit model’ approach to science communication. He asserts that the deficit model assumes a top down communication in which scientists and science communicators contribute to improving the scientific understanding of non-experts. They do so by teaching them science in a traditional way. An expert dictates and a student follows (Cullen et al., 2007). This deficit model is based on three assumptions (Brossard et al., 2005; Coalition on the Public Understanding of Science, 2006; Gregory and Miller, 1998; Lewenstein, 2002, 2003 in (Bell et al., 2009)). The first is that the public tends to be ignorant of scientific facts and processes. The second assertion is that science is neutral and objective and thus has the wisdom and answers to fill in the deficit. Finally, according to the deficit model, the ignorance of science is detrimental to a thriving society.

There are a great number of authors that argue the limitations of the assumptions of the deficit model and therefore believe the public understanding approach of science must be rejected (Davies et al., 2009; Falk et al., 2007; Irwin, 1995). Their views emerge from studies that document that the
public can be critical consumers of science. These critics of the public understanding of science approach propose public engagement of science as the model to guide activities of science communication (Bell et al., 2009; Cullen et al., 2007). The next section analyses this approach to science communication.

1.2.1.2 Public Engagement with Science

The public engagement of science approach was thus introduced by those who criticized the public understanding of science (Bell et al., 2009). It is argued that the public engagement of science approach should be used and the public understanding of science model should be rejected.

The public engagement with science approach represents a two-way dialogue between specialists and non-specialists, in which mutual learning is the goal. It assumes that scientists are not the only ones that have expertise to share with the public. The public itself has expertise, valuable perspectives and knowledge for contributing to the development of Science and its applications (Burns et al., 2003; Kerr et al., 2007; Leshner, 2003). The dyad Public Understanding of Science/Public Engagement with Science can be seen in a continuum in which the public and scientist roles vary.

Bell et al. (2009) purpose a framework to discriminate between activities that follow an understanding or an engagement approach. The authors suggest three dimensions to classify activities. The three dimensions are presented in figure 1.2.

Figure 1.2 Three dimensions that separate Public Understanding of Science (PUS) from Public Engagement with Science (PES) (Adapted from Bell et al., 2009)

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Description</th>
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<tr>
<td>1 - How is the public involved in the PUS or PES activities?</td>
<td>A scale with five different answers establishes the relative position of each activity, that is to say whether it is more orientated to PUS or to PES. As such, they vary from 1, where knowledge and ideas flow to the public participant, to 5, where they flow from the public participant.</td>
</tr>
<tr>
<td>2 - How are people with specific expertise related to STEM involved in the activity?</td>
<td>In this dimension, the approach can either have the experts to support the public communication efforts of others or to incorporate the public’s thinking into the decisions concerning the experts’ work.</td>
</tr>
<tr>
<td>3 - What is the content focus of the activity?</td>
<td>This last dimension ranges from understanding the natural world to understanding the processes of societal decision making and public policy related to Science and technology.</td>
</tr>
</tbody>
</table>

The three dimensions define a continuum between the public understanding of science and the public engagement of science approach, as seen in figure 1.3. Thus, they are the tools that classify activities along this continuum.
As seen in figure 1.3, the bottom left corner represents activities that follow a public understanding of science approach while the top right one represents activities that follow a public engagement of science approach. Bell et al.’s (2009) framework was conceived for the classification of informal science education activities. The authors use the public understanding of science and public engagement of science approaches to classify informal science education activities.

After analysing how science communication can be defined according to formal responses to science it aims to produce in society and the two main approaches to produce these responses, the next section delves into informal science education.

1.2.2. Informal science education

Although often compared to science communication, informal science education has a different origin and different objectives. Crane et al. (1994) were one of the first authors to define informal science education:

Informal science education refers to activities that occur outside the school setting, are not developed primarily for school use, are not developed to be part of an ongoing school curriculum and are characterized as voluntary as opposed to mandatory participation as part of credited school experience. (Crane et al., 1994, p. 3)

Informal science education occurs in a variety of settings, such as museums, science centres, university programs, media programs and community programs. Therefore, informal science education encompasses the vast majority of experiences that, across their lifetimes, people may have with science (Bell et al., 2009). Wellington (1991) catalogues some of the features that are often used to distinguish formal from informal learning in science, when discussing the role of science in newspapers. The author states that informal learning is characterized by being volunteer, unstructured, non-assessed and learner led.
Bell et al., (2009) give a more recent definition of informal science education than the ones presented by Crane (1994) or Wellington (1991). The authors propose a framework with strands of science learning that articulate science-specific capabilities supported by informal environments, as seen in figure 1.4.

Figure 1.4 Strands of learning in informal science education

<table>
<thead>
<tr>
<th>Strand 1: To experience excitement, interest, and motivation to learn about phenomena in the natural and physical worlds.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strand 2: To generate, understand, remember, and use concepts, explanations, arguments, models, and facts related to Science.</td>
</tr>
<tr>
<td>Strand 3: To manipulate, test, explore, predict, question, observe and make sense of the natural and physical worlds.</td>
</tr>
<tr>
<td>Strand 4: To reflect on Science as a way of knowing, as well as on learning processes and concepts, and institutions of Science.</td>
</tr>
<tr>
<td>Strand 5: To participate in scientific activities and learning practices with others, using scientific language and tools.</td>
</tr>
<tr>
<td>Strand 6: To think about themselves as Science learners, and to develop an identity as someone who knows about, uses, and sometimes contributes to Science.</td>
</tr>
</tbody>
</table>

When compared to science communication, informal science education is more directed towards the learning of science. The strands of learning defined for informal science education overlap with science specific knowledge developed at school (Bell et al., 2009; Feder et al., 2009). Strands one and six are considered particularly relevant to informal learning (Bell et al., 2009). It is argued that informal science education can help to increase the interest of students in science, which is lacking (Regan, 2009; Stocklmayer et al., 2010)

However, the role of informal science education suffers from ambiguity. According to Bell et al., (2009, p. 18), “with the growth of interest in informal science education, the diversification of venues, practitioners, and researchers, the literature has developed in a fractured and uneven manner”. There are three key limitations of informal science education summarized in figure 1.5 below. Furthermore, Fallik et al, (2015) acknowledge the limitation of separating formal and informal science education. As stated by the authors: “although the formal and informal science education institutions in a community have historically been considered as separate systems, they should not be, since there are large overlaps in both audience and espoused goals” (p. 146)

Figure 1.5 Three key limitations of informal science education (Adapted from Bell et al., 2009; Falk et al., 2015; Feder et al., 2009; Stocklmayer et al., 2010).

<table>
<thead>
<tr>
<th>1st Limitation</th>
<th>The relationship between schools and informal environments for Science learning has been unclear and contested, serving as an impediment to integration of what is understood about learning across these settings</th>
</tr>
</thead>
<tbody>
<tr>
<td>2nd Limitation</td>
<td>Since many fields of inquiry are invested in informal science education, the research base reflects a diversity of interests, questions, and methods from several loosely related fields</td>
</tr>
<tr>
<td>3rd Limitation</td>
<td>The goals of informal science education are multiple and somehow disperse as they involve different publics</td>
</tr>
</tbody>
</table>

The three limitations presented in figure 1.5 reveal that the field of informal science education is dispersed. Therefore, to attain very specific objectives, such as increasing the interest of students in
science and science careers, a more precise approach is needed. It is in this context that science outreach is gaining relevance.

1.2.3. Science outreach for primary and second level students

Outreach is also a term with multiple meanings in the literature. In the context of science, science outreach is used to refer to the efforts of knowledge transfer from scientists to the public, particularly in terms of initiatives designed to develop and maintain young people’s interest in science and science careers (Bell et al., 2009). It consists of an array of activities and programs developed by universities, community organizations and state agencies to foster primary and second level students’ involvement/literacy in science (Stanford, 2014). Digas et al. (2007, p.1) define science outreach as the act of “seeking” and “reaching” out to our nation’s youth and encouraging them to consider the science disciplines as a career choice. By combining the definitions of Bell (et al., 2009), Stanford (2014) and Digas et al. (2007) it is possible to conclude that the target audience for science outreach is primary and second level students, our nation’s youth, and its objective is to increase their interest, involvement and knowledge of science.

Science outreach for primary and second level students is more closely related to formal science education when compared to science communication and informal science education. In the literature, as described above, science outreach focuses specifically on primary and second level students. This is in opposition to informal science education and science communication that target the general public. As it focuses on primary and second level students, science outreach has two main objectives: encouraging students to consider a science career and improving students’ scientific education experience (Bell et al., 2009; Digas et al., 2007; Jeffers et al., 2004). The two objectives of science outreach involve students, which makes it relevant for formal science education.

Stocklmayer et al., (2010) introduce the concept of the third space to highlight the relevance of science outreach in the formal science education sector:

The third space (…) is the potential real space in which the informal sector can move, bridging the gap between school and community and hence blurring the boundaries between them. The space is currently quite empty, occupied here and there by an enthusiastic scientist; an outreach program from a Science centre or a university. (…) Critically it (the third space) requires acknowledgment from the world of formal education that help is needed, that all cannot be solved from within the system and that yet another new curriculum will not solve the problems of science education (Stocklmayer et al., 2010, p. 30).

Here, Stocklmayer et al., (2010) are insisting that science education has many problems that cannot be solved within the system. There is a deficit in the formal education sector that is not being dealt with. Outside actors are trying to remediate those problems. Although they face a challenge, it is argued that these efforts are being pursued through sporadic and incoherent activities. This issue will be addressed further in Chapter two.

Insights from the previous sections justify why science outreach for primary and second level students is the practice that can better occupy this empty third space. Both informal science education and science communication are disciplines directed to the general public. As they aim to influence “people of all ages and backgrounds” in relation to science (Bell et al., 2009, p.42), science
communication and informal science education represent approaches with multiple and disperse goals (Bell et al., 2009; Burns et al., 2003). On the other hand, science outreach is specifically directed towards primary and second level students. Moreover, science outreach for primary and second level students also has the specific goal of raising students’ knowledge and interest in science and science careers. As the research carried out by Henriksen et al (2015) has shown these objectives are pursued through different types of activities. These can be out of school experiences that target recruitment efforts. Henriksen et al (2015) conclude that long term efforts seem to be more powerful in students’ decision process than targeted recruitment efforts. The authors suggest that stakeholders wishing to improve science participation need to consider partnerships with educational institutions. Fallik et al (2013, p. 69), in their review of formal and informal learning, also conclude that there is “a serious lack of contact between formal and informal learning contexts that teach the same concepts” and recognize “the need to create productive collaborations between informal science education organisations and schools” (p.70)

Therefore, in spite of its potential to fill the third space, science outreach still lacks a structured approach with clear methods (Neuroscience Editor, 2009). As suggested by Henriksen et al (2015) and Fallik et al (2013), developing partnerships with formal science education may address this concern. How these partnerships can fruitfully work is still a contested and debated field (Stocklmayer et al., 2010)

This study is centred precisely on the problematic relation between science education and outreach. Specifically, due to recent implementation of the science primary curricula in Ireland and the outreach initiatives existent at this level, this study explores the relationship between science education and outreach at primary level in Ireland.

1.2 Rationale for the study

This study analyses the pedagogical relationship between science outreach and science education, in the context of primary level education in Ireland. Figure 1.6 frames the three spaces that guide this study.
Figure 1.6 Three spaces that guide this study

**First Space (Education)**

Transmissive methods common (McCoy et al., 2012).

Primary level teachers not confident to teach Science (Varley et al., 2008).

Recent science curriculum at primary level (DES, 1999)

End of primary level, most pupils have ruled out science (Van Aalderen-Smeets et al., 2012)

**Second Space (Outreach)**

Potential to improve student engagement to be a direct vehicle in assisting science education (European Commission, 2007)

Does not suffer from constraints of formal education (Stocklmayer et al., 2010)

Not aware of what happens in a classroom or curriculum content/sequence (NeuroScience Editor, 2009)

No clear methodological basis (Stocklmayer et al., 2010)

**Third Space**

Incorporating outreach into daily school work (Stocklmayer et al., 2010)

Needs further connection with schools and curricula (NeuroScience Editor, 2009)

Need to understand what outreach brings different to the classroom (Bell et al., 2009; Stocklmayer et al., 2010)
The first space is science education at primary level in Ireland. In 2003, a primary level curriculum for science, based on constructivist methods, was introduced. This curriculum emphasises autonomy, inductive-inquiry activities, and creativity. Nevertheless, studies carried out in Ireland have revealed that transmissive methods are still the most commonly used by teachers (McCoy et al., 2012). Furthermore, it is argued that primary level teachers do not feel confident when teaching science (Varley et al., 2008) and at the end of primary level most pupils have already excluded the choice of scientific subjects (Van Aalderen-Smeets et al., 2012, p.2).

The second space that guides this study is science outreach initiatives. This study is focused in university driven science outreach because it forms the majority of outreach initiatives in Ireland (Davison et al., 2008). These initiatives are seen as having the potential to improve student engagement with science (European Commission, 2007; Stocklmayer et al., 2010). Moreover, it is argued that science outreach can integrate inquiry learning more effectively in the classroom, in accordance with curricular reforms (European Commission, 2007). It is in this context that the concept of the third space is argued by Stocklmayer et al. (2010). The authors believes that students, participating regularly in these outreach initiatives, can benefit from more active, autonomous and creative learning. It is maintained that outreach practitioners do not suffer from the constraints of formal education systems; therefore, they can more easily create this type of environment for students (Stocklmayer et al., 2010). Nevertheless, science outreach programs are still considered to be sporadic and incoherent, lacking a structured approach with clear methods and aims (Stocklmayer et al., 2010). To contribute to the creation of the third space, science outreach needs to further develop connections with schools (European Commission, 2007). There is a need to create hybridization between the agents of the first and second so that the third space can be a reality. Thus, there is a need to analyse and compare the views that teachers and outreach practitioners have regarding the objectives envisaged by curricular reforms, in order to understand the potential of this third space. To achieve this aim, this study follows a mixed methods methodology through a triangulation design and convergence model. The overall aim, main research questions and research objectives are now presented.

1.3 Overall aim and research questions

The overall aim of the research is to examine and compare primary teachers’ and science outreach practitioners’ understanding and perception of constructivist science teaching pedagogy, in order to improve the hybrid practice of science education/outreach in Ireland.

The research objectives of this study, that are addressed within the literature review, are as follows:

- To analyse the current state of science education: identify objectives and practices of science education and specifically science education at primary level;
- To analyse science outreach policy documents and reports: identify key objectives and practices of science outreach;
- To analyse constructivism in science education;
- To analyse learning models of the information processing family that have been applied to science education: To investigate how different learning models can benefit science outreach activities.

The methodological phase of this research is guided by research questions, which are outlined here:
RQ 1: What are primary teachers’ and science outreach practitioners’ understanding and perceptions of constructivist science teaching pedagogy?
  o 1.1 How do primary teachers and science outreach practitioners understand conceptual and pedagogical dilemmas in science teaching and learning?

RQ 2: What perceptions do primary teachers and science outreach practitioners have in relation to the multiple dimensions of a constructivist teaching and learning environment?
  o 2.1 Does the biological sex of the primary level teachers impact the perception of a constructivist learning environment?
  o 2.2 Does school size (large/small) impact the perceptions of primary teachers in relation to a constructivist teaching and learning environment?
  o 2.3 Does having outreach initiatives in the classroom impact the perceptions of primary teachers in relation to a constructivist teaching and learning environment?
  o 2.4 Does the biological sex of the outreach practitioner have an impact on their perception of a constructivist learning environment?
  o 2.5 Do different categories of outreach practitioner have differing perceptions of a constructivist teaching and learning environments?
  o 2.6 Does frequency of outreach activities impact the perceptions of outreach practitioners in relation to a constructivist teaching and learning environment?
  o 2.7 What differences/similarities arise when teachers and outreach practitioners are asked to give their perceptions of a constructivist teaching and learning environment?

Table 1.1 presents a holistic view of the research gaps, questions, objectives, method and analysis.
### Table 1.1 Research Overview: Gaps, Questions, Methods and Analysis

<table>
<thead>
<tr>
<th>Research Gaps</th>
<th>Research Question (RQ) and Research Objectives (RO)</th>
<th>Method</th>
<th>Analysis</th>
</tr>
</thead>
</table>
| Lack of unified understanding in relation to the objectives and origins of science outreach | RO 1: To analyse the current state of science education: identify objectives and practices of science education and specifically science education at primary level  
RO 2: To analyse science outreach policy documents and reports: identify key objectives and practices of science outreach | Literature Review (Deductive logic)                                                                                                   | N\a                                                                                           |
| Lack of educational basis for Science Outreach (weak methodological basis; /little connection with curricula) | RO 3: To analyse constructivism in science education  
RO 4: To analyse learning models of the information processing family that have been applied to science education: To investigate how different learning models can benefit science outreach activities | Literature review (Deductive logic)                                                                                                   | N\a                                                                                           |
| Lack of reported understanding of views of outreach practitioners and primary level teachers when presented with conceptual and pedagogical dichotomies in relation to a constructivist teaching and learning approach | RQ 1: What are primary teachers’ and science outreach practitioners’ understanding and perceptions of constructivist science teaching pedagogy?  
1.1 How do primary teachers and science outreach practitioners understand conceptual and pedagogical dilemmas in science teaching and learning? | Interview method (Deductive and inductive logic)                                                                                           | Descriptive statistics  
Chi-square for the goodness of fit  
Man-Whitney test  
Kruskal-Wallis test  
Constant comparative coding process |
| Lack of understanding about how different factors (sex, school size, years of teaching) affect primary level teachers views of constructivist learning environments | RQ 2: What perceptions do primary teachers and science outreach practitioners have in relation to the multiple dimensions of a constructivist teaching and learning environment?  
Sub questions;  
2.1 Does the biological sex of the primary level teachers impact the perception of a constructivist learning environment?  
2.2 Does school size (large/small) impact the perceptions of primary teachers in relation to a constructivist teaching and learning environment?  
2.3 Does having outreach initiatives in the classroom impact the perceptions of primary teachers in relation to a constructivist teaching and learning environment? | Survey Method (Deductive logic)                                                                                                           | Descriptive statistics  
logistic regression  
general linear model                                                                                         |
| Lack of understanding about how different factors (sex, role, frequency of outreach) affect science outreach practitioners views of constructivist learning environments | 2.4 Does the biological sex of the outreach practitioner have an impact on their perception of a constructivist learning environment? 2.5 Do different categories of outreach practitioner have differing perceptions of a constructivist teaching and learning environments? 2.6 Does frequency of outreach activities impact the perceptions of outreach practitioners in relation to a constructivist teaching and learning environment? | Survey Method (Deductive logic) | Descriptive statistics logistic regression general linear model |
| Lack of a comparison between science outreach practitioners and primary level teachers views in relation to learning environments | 2.7: What differences/similarities arise when teachers and outreach practitioners are asked to give their perceptions of a constructivist teaching and learning environment? | CLES Survey (Deductive logic) | Descriptive statistics logistic regression general linear model |
To address the research questions this study follows a dialectic pragmatic stance. Dialectic pragmatism emphasizes that “pragmatism for mixed methods takes quantitative and qualitative methods seriously but then develops a synthesis of the research study” (Teddlie and Tashakkori, 2009, p.73). As this study uses different methods, it employs deductive and inductive logics to address the confirmatory and exploratory research questions (Johnson and Onwuegbuzie, 2004), as it evident in table 1.1. Within this paradigm, two research methods are employed, the Constructivist Learning Environment Survey (CLES) and a semi-structured interview.

Overview of research methods

This research adopts a two phase methodology which begins with a literature review in phase one. Phase two corresponds to the methodology section of this thesis. A summative overview of the two phases that comprise this thesis is now presented in figure 1.7.

**Figure 1.7 Summative overview of the two phases of the study**

<table>
<thead>
<tr>
<th>Phase I Literature review</th>
<th>Phase II – Mixed Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Policies and practices of science education</td>
<td>Data collection tools</td>
</tr>
<tr>
<td>Policies, objectives and practices of science outreach</td>
<td>Sample groups</td>
</tr>
<tr>
<td>The need to understand the role of science outreach by comparing science outreach and education according to constructivist concepts</td>
<td>Justification of approach to sampling</td>
</tr>
<tr>
<td>The need for stronger methodological and educational basis for science outreach</td>
<td>Dialectic pragmatism as the research paradigm of the study</td>
</tr>
<tr>
<td>Constructivism as the philosophical basis for science education and science outreach</td>
<td>Ethics and Incentives</td>
</tr>
<tr>
<td>Dialectic dichotomies as a novel basis to compare science education and science outreach</td>
<td>Data analysis procedures for the semi-structured interview</td>
</tr>
</tbody>
</table>

Phase one begins in Chapter two with the examination of science education and science outreach, starting with the analysis of the current state of science education policies. This analysis emphasizes the context within the Republic of Ireland, contextualised with examples from other countries. It continues by discussing how the different policies are implemented within different curricula and in teachers’ practices. The current state of science education facilitates the understanding of the origin and progression of science outreach practices. This presentation includes the analysis of the objectives of science outreach, the policies that guide it, and its methods. This analysis concludes that science education reforms are guided by constructivist epistemology. Furthermore, two main theoretical gaps are identified. The first gap is the need to understand the role of science outreach in primary level by comparing science outreach and education according to constructivist conceptualizations. The second gap is the need for a stronger methodological basis for science outreach and for the role of curricular models of science education for this purpose.

Therefore, the literature review continues in Chapter three by explaining the philosophical and educational ideology that influences science education and outreach, constructivism. It further details how dialectical models are applied to constructivism in science education. It continues by discussing a constructivist dialectical model that defines dialectic dichotomies that are relevant for the comparison of science education and outreach.
The dialectic dichotomies that guide this study need to be adapted to science education, and specifically, science education at primary level. **Chapter four** provides the contextualised basis for the dichotomies. To do so, in **Chapter four** models of teaching and learning are discussed to emphasize the educational concepts and processes.

**Phase two** starts in **Chapter five**, which explains the mixed methods research approach followed by this study. A semi-structured interview and the CLES survey are used to address the methodological research questions. According to Creswell and Clark’s (2007) typology, this study follows a mixed methods design through a triangulation design and convergence model. Quantitative data is obtained through the CLES survey. Concurrent with this, qualitative and quantitative data are obtained through a semi-structured interview format. The triangulation design is a one phase-design (Creswell and Clark, 2007). Both strands are planned and designed to answer different aspects of the research questions, as presented in table 1.1. Inferences of both phases are then integrated within the analysis, making it a convergence model.

In **Chapter six**, non-parametric tests are used to analyse the quantitative responses of the interview, specifically the Mann-Whitney and the Kruskal-Wallis test. The qualitative responses of the interview were analysed according to principles of the constant comparative coding process. The coding process followed guidelines by Boeije (2010).

In **Chapter seven**, ordinal logistic regression and general linear model tests are carried out to analyse the quantitative survey data. The ordinal logistic regression enables detecting and describing relationships among variables (Pallant, 2010). The General Liner Model (GLM) tests for significant differences between groups (Pallant, 2010).

Finally, in **Chapter eight**, according to the dialectic pragmatic stance followed here, a synthesis of the results is developed. The Chapter further highlights the implications and contributions of the study.
1.4 Biographical motivation

My interest in science outreach began during my undergraduate degree in Biology. I entered University with the intention of completing a masters degree in Biology Education. As such, since my undergraduate in Biology, I always had an interest in the educational aspect of science and pursued opportunities to develop science activities with primary and second level students. In my early University days, at Lisbon University, I began doing science open days for primary and second level students. As I really enjoyed the informal nature of these activities, I started a part time job for Mad Science where I developed science clubs for primary and second level schools, science summer camps and science parties. This informal nature of science outreach and its ethos of hands on constructivist became even more important when I started studying for my education masters degree. I encountered constructivism, when doing my science teaching degree, initially as learning theory(ies) for education, mainly through the works of Jean Piaget, Jerome Brunner, Lev Vygotsky and Simon Papert. Constructivism in its different faces and its positive influence on science education was something that I immediately recognized and of which I found evidence in the literature. When completing my teacher training year I continually applied constructivism through inquiry learning in my teaching. This was the first time I discussed my interest extensively with fellow teacher colleagues and they started revealing the issues and problems they faced in day to day teaching. Since then I have always been interested in the role of outreach in education and in the promotion of hands on and constructivist practices.

When I moved to Ireland, I continued to implement outreach activities. First, I conducted after school science clubs in schools and after, I contributed to science summer camps and science festivals in the University. When I got the opportunity to enrol in a PhD in education, my dual nature as a science teacher and science outreach practitioner was key in developing my theme. As I read more papers, delved into the research and reflected, my motivation was drawn towards the relationship between formal and informal science education.
Chapter Two: Science education and science outreach for primary and second level students
2.1 Introduction

Improving science education is a concern of Irish and other European governments. Due to the economic relevance of science, policy makers aim to increase student engagement in Science (Davison et al, 2008; Osborne and Dillon; 2008; Regan, 2009). Moreover, governments seek to encourage students to pursue science degrees (DETI, 2009; European Commission, 2007; Osborne and Dillon; 2008).

In order to achieve this twofold objective several measures have been developed by policymakers throughout the world (European Commission, 2011; Osborne et al., 2008). In the case of Ireland, science curriculum reforms were made in the primary level education system, with the introduction of a new curriculum in 2003, and further reform is underway at second level (DES, 1999; NCCA, 2013). The reforms argue for inquiry learning based methods, rooted in constructivist epistemology (Llewellyn, 2002; Matthews, 2002, National Research Council, 2011). In spite of curricular developments, several reports emphasize that science education is not changing, with deductive teacher led lessons being the norm (McCoy, et al., 2012). Therefore, new ways of engaging primary and second level students with science have been pursued, one of which is by urging universities and research institutions to become more involved in primary and second level science education through science outreach programmes. Many intervention strategies have already been trialled in Ireland, particularly to target participation in the sciences and gender equity (Regan, 2009 p.262). It is argued that science outreach programmes have the potential to integrate more inquiry learning in the science classroom and ideally impact an increasing interest in science (European Commission, 2007; Stocklmayer et al., 2010). In spite of the positive effects claimed, science outreach programmes are still considered sporadic and incoherent without a structured approach or clear methods and aims (NeuroScience Editor, 2009). Science outreach can only fulfil its potential if its aims and practices are understood (Stocklmayer et al., 2010).

In response, the aim of this Chapter is to understand the current condition of science outreach in primary and second level education. This cannot be achieved without discussing the discipline that most influences it, science education. Therefore, the initial section of this Chapter starts by analysing the current state of science education policies. This analysis emphasizes current practice in the Republic of Ireland, contextualised with examples of other countries. Discussion reveals how various policies impact the different curricula and therefore the teacher’s practice. The current state of science education is presented and demonstrates the origin and establishment of science outreach practices. This is followed by an analysis of the objectives of science outreach, the policies that guide it and its methods.

2.2 Science education, a broken system in need of remedy?

Calls to change the way science is taught in schools are common in the field of science education. In recent years, many government institutions have renewed these calls, emphasising the importance of bringing more students to science. The arguments being made and the reasoning behind them are now examined.

2.2.1 The push for science: an economic argument for science education

In the developed world, science has become important economically. The idea of a scientific society that needs an increasing number of science graduates in the workforce is dominant (Osborne
and Dillon, 2010). Policy documents of several countries emphasize these aspects, as represented in figure 2.1.

Four views are presented in figure 2.1. Sackett (2010) urges the Australian government to take action in face of the decline of students enrolled in science. The American White House (2010) similarly wants to see more science education and career opportunities being given to students. Also, Ireland and the European Union reveal a concern in relation to this issue. The European Commission (2007) High Level Group on Science cautions about the diminished interest of students in science, recommending more effective action to reverse the trend. The Irish Government goes even further in their call for science. In Ireland, the Minister for Jobs and Innovation (SFI, 2014b) states that the country needs more graduates in scientific areas to develop sustainable economic growth. This concern stems from the statistics from the European Commission (2011) that revealed that Ireland was the only country that was not catching up or moving ahead of the European Union target level of 12.6 graduates. Three main inferences can be drawn from the reports from where these quotes were taken.

Firstly, the reports stress that science and technology graduates are fundamental for the economic growth of these countries. It is their belief that a technological society, as the one we live in, demands a constant supply of scientists to sustain economic growth and international competitiveness. Secondly, the reports reveal concern and alarm in relation to the number of students that are following science related careers. They all emphasize decline in the number of students, and decrease in interest of key science disciplines. Thirdly, the reports recognize that more needs to be done to encourage students to pursue science careers. These arguments illustrate a global trend with respect to science education, extensively reported in the literature (Osborne and Dillon, 2008; Regan, 2009; Regan and De Witt, 2015; Stocklmayer, et al., 2010). Smith and Gorard, (2011, p.159) disapprove of the “pressure to retain or even increase the number of scientists in the
UK and other developed countries”. Smith and Gorard (2011) argue that there may be too many science graduates for the labour market, as their analyses reveals that the majority of science graduates then move into initial occupations that are not directly related to their degree. In spite of this criticism from Smith and Gorard (2011), the notion of the need of an increasing number of science graduates in the workforce is prevalent.

A core objective of the aforementioned reports is to change science education. Furthermore, they want to change it in a way that enables more students to follow scientific career paths. The questions that arise are: what is the current state of science education and what change is argued? The next section addresses these questions.

2.2.2 Curricular change in science education

Changing science education to make it more engaging and meaningful for students is not a new objective (Schwab, 1963; Suchman 1960). Schwab (1963) was one of the first researchers to design a model for science education that challenged the “traditional way of teaching” (Schwab, 1963, p.21). Since then, many authors have questioned the way science is taught in schools (Aikenhead, 2006; McCoy et al. 2012, Osborne and Dillon, 2010).

Nevertheless, a more institutional call for reform with widespread impact started with the Report ‘A nation at risk : A call for widespread reform’ (National Commission on Excellence in Education, 1983), in the USA, and with the Public Understanding of Science movement, in the UK (Miller, 2001). Stocklmayer et al. (2010) present a key issue acknowledged in these reports:

How can school science education both prepare some students to go on to careers in Science and technology and prepare all students to be responsible, scientifically literate citizens? (p. 2)

This question reveals the twofold objective that guides worldwide curricular reform in science education: to form science literate citizens and to prepare some of them for careers in science. One of the most relevant policy documents in science curricular reform is the National Science Education Standards’ (National Research Council, 1996) report, published in the USA. This document argues for a type of science education that, according to the authors, can fulfil both objectives:

Science teaching must involve students in inquiry-oriented investigations in which they interact with their teachers and peers. Students establish connections between their current knowledge of science and the scientific knowledge found in many sources; they apply science content to new questions; they engage in problem solving, planning, decision making, and group discussions; and they experience assessments that are consistent with an active approach to learning. Emphasizing active science learning means shifting emphasis away from teachers presenting information and covering science topics (National Research Council, 1996, p. 20).

The national science education standards (National Research Council, 1996) emphasize inquiry learning and learning of science by doing. It is claimed that learning science is something that students do, not something that is done to them. More recent reports of the National Research Council have supported a constructivist approach to science learning (National Research Council, 2011; Llewellyn, 2002).
Constructivism provides the philosophical foundation for the science standards (National Research Council, 1996). It is offered as a direct alternative to the dominant traditional model (Sawyer, 2008), that relies on top down communication. The opposing schools’ of thought projected by a constructivist view of teaching and learning, also influenced curricular reforms in Europe.

The Rocard report produced by the European Commission (2007) is a key policy document for science education in Europe. The European Union does not have a mandatory education policy; it is the role of the European countries to do this through their science curricula. That said, policy documents can impact change in different European countries, in particular through funded research in science education (CORDIS, 2014). The Rocard report (European Commission, 2007), convened by a group of experts, addresses the problem of student uptake in science and makes recommendations. The experts concluded that the declining interest in science studies among students is as a result of the way science is being taught in schools. (European Commission, 2007). Therefore, they suggest how science education should change to increase interest in science: “a reversal of school science-teaching pedagogy from mainly deductive to inquiry-based methods provides the means to increase interest in science” (p.2). The authors argue that inquiry based methods create the “most favourable conditions and attitudes (interest, self-confidence) to reach the deepest levels of knowledge for the most talented, creative and motivated students” (p.12). Once again, the favoured leaning towards constructivism rather than the traditional model is highly visible. Such claims are supported by evidence presented by several authors such as Koksal and Berberoglu (2014) who documented the positive effect of guided-inquiry approach on sixth grade turkish students' cognitive as well as affective characteristics. Also, the research of Jocz et al (2014) into the inquiry model publishes findings that suggest inquiry learning can increase Singaporean students’ interest in school science when it emphasizes the everyday applications of science and allows for peer discussion.

Science is a key priority of the Irish government. Furthermore, science uptake by Irish students is a concern of the government, which is particularly evident in the recent European Union report that analysed the number of graduates in science fields. Ireland was the only country that was not catching up or moving ahead of the European Union target level of 12.6 graduates per 1000 young people in the area of Mathematics, Science and Technology (European Comission, 2011). The Irish government Strategy for Science, Technology and Innovation 2006 – 2013 (DJEI, 2006) put great emphasis on science education as a tool to increase the number of students following scientific careers. It emphasised primary education, which is considered a key level to motivate students for Science (European Commission, 2007; Tytler, 2008).

The science curriculum is the official policy document for science education in Ireland. Inquiry learning is stressed in both the primary and post-primary level curriculum (DES, 1999). The new primary science curriculum is a very recent ‘add-on’ to the Irish Education System. It began implementation just over ten years ago (school year 2003/2004). The recommended pedagogy in the curriculum aligns with the constructivist and inquiry based methods echoed in the reform movement, as outlined in figure 2.2.
The curriculum advocates that students need to plan, design and perform investigations in order to learn and make sense of science. It is an approach that once again values inquiry learning and problem solving. Furthermore, the curriculum values explicitly a constructivist approach. This constructivist approach recommends starting from the child’s ideas and favouring a developmental view. Finally, as in the European report (European Commission, 2007), creativity in science and in the learning of science is highlighted. This aligns with other school curricula as “creative thought is often a stated goal of education” (Regan, 2011, para 2).

This section started by showing how science has become economically important to governments and continued by demonstrating that governments are concerned in relation to the numbers of students in science and how they demand a change in science education. Through the analysis of several documents, it revealed that this change emphasizes inquiry learning, rooted in constructivism, as opposed to the traditional model. Furthermore, the alignment of the Irish Curriculum with the reform movements was presented; emphasizing inquiry, autonomous learning and creativity. The next section explores how curricular reforms are viewed by teachers.

### 2.2.3 From curricular guidelines to practice in schools: dilemmas faced by teachers

The effectiveness of science education was questioned in the previous sections and partially answered by exposing different standards and curricula. The curricula, national science education standards and reports referred to favoured practices of inquiry learning. These reforms have been strongly influenced by science education literature that reflects a constructivist philosophy (Matthews, 2002; Savasci and Berlin, 2012; Tobin and Tippins, 1993). De Boer (1991) highlights the relevance of inquiry in science education with the assertion: “If a single word had to be chosen to describe the goal of science education during the 30-year period that began in the late 1950s, it would have to be inquiry” (p. 206). Recent reports continue to emphasize inquiry learning as the main goal of science education (Bell et al., 2010; Blanchard et al., 2010; Bybee et al., 2006; Hmelo-Silver et al., 2007; Singer et al., 2000). To complement this pedagogical analysis within science education, the implementation of these reforms by teachers is now discussed.

Stocklmayer et al.’s (2010) review of published reports highlights the little success that has emanated from these reforms:
There have been many attempts to change the way Science is taught, endeavouring to increase the quality, or meaningfulness of students learning. None of these efforts have so far been effective in initiating sustained change on a wide scale (p. 6).

In other words, Stocklmayer et al. (2010), which base their assumptions on several international studies (National Research Council, 2011; OECD, 2010), report that science education teaching still relies on the traditional method. This happens in spite of the aforementioned reforms. The TALIS (OECD, 2010) international survey programme concludes that teachers in Ireland use the traditional model of teaching even more than teachers in other countries. National reports corroborate these findings:

The 2009 National Assessments showed that Irish classrooms at second and sixth class levels are predominantly characterised by whole-class teaching and by pupils working by themselves (rather than in pairs or in small groups), as well as by the use of textbooks, reading schemes, and workbooks. These findings suggest that constructivist teaching approaches in the classroom remain relatively rare compared to more “traditional” methods of instruction (Eivers and Clerkin, 2013, p. 78).

Several authors have discussed reasons that explain the reluctance to change shown by teachers (Stocklmayer et al., 2010; Windschitl, 2002). First, there is a lack of professional developmental to help teachers to implement the new curricula. Second, there is a constant attrition of young teachers leading to disillusion with the systems in place in schools and their inability to effect change.

Further, in the literature, salient issues such as teachers’ beliefs, self efficacy and pedagogical content knowledge are put forward to explain the lack of sustained change in spite of curricular reforms (Gess-Newsome, 1999; Hammerness et al., 2007; Levitt, 2002; Mints and Marcum 2012; Pajares, 1992; Smith and Southerland, 2007; Shulman, 1987; Thomson and Gregory 2013). For instance, Thomson and Gregory (2013) conclude that research shows that the shift to teaching practices that support a constructivist instructional approach will first require changing teachers’ beliefs about science teaching and learning altogether. Moreover, studies suggest that beliefs influence teachers’ decision processes, and changes in beliefs can be a core pre-requisite to real change in the classroom (Dixon and Wilke, 2007; Grove et al., 2009; Mansour, 2009). Mintzes and Marcum (2012) report the relevance that self-efficacy plays in implementing constructivist practices. Self-efficacy is defined as “judgments about how well one can organize and execute courses of action required to deal with prospective situations that contain many ambiguous, unpredictable, and often stressful, elements. The authors state that the highest levels of self-efficacy are found in those who have a strong science background and an inclination to engage in reform-based teaching practices. This leads to research such as the one by Kanter and Konstantopoulos (2010) that states the core relevance of content knowledge and pedagogical content knowledge. As stated by Kanter and Konstantopoulos (2010, p. 174)“if teachers are lacking in content knowledge or pedagogical content knowledge, they may not be able to employ the inquiry-based aspects”

Although the above mentioned reasons are relevant, Windschitl (2002) has framed the reluctance of teachers to change in constructivist terms. The author defines dilemmas as the difficulties teachers face when implementing constructivist inquiry learning, as represented in figure 2.3. These dilemmas help us to understand why inquiry learning is still the exception in science teaching.
Figure 2.3. Dilemmas in constructivist teaching, adapted from Windschitl (2002)

<table>
<thead>
<tr>
<th>Conceptual dilemmas</th>
<th>Pedagogical dilemmas</th>
<th>Cultural dilemmas</th>
<th>Political dilemmas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rooted in teachers’ attempts to understand the philosophical, psychological, and epistemological underpinnings of the change towards an inquiry based learning philosophy.</td>
<td>Arise from the more complex approaches to designing a curriculum and fashioning learning experiences that inquiry based learning demands.</td>
<td>Emerge between teachers and students during the radical reorientation of classroom roles and expectations necessary to accommodate the inquiry based learning ethos.</td>
<td>Associated with resistance from various stakeholders in school communities when institutional norms are questioned and routines of privilege and authority are disturbed.</td>
</tr>
</tbody>
</table>

The four dilemmas, or dimensions as Windschitl (2002) also names them, reflect an ecological view of the difficulty that arises when implementing change in education, in constructivist terms. The ecological view acknowledges that the four dimensions are connected and if one fails it can compromise change. Therefore, for a sustained change the teacher needs to acknowledge the four dimensions. First, the teacher needs to grasp the underpinnings of cognitive and social constructivism. Second, the teacher needs to honour students’ attempts to think for themselves while remaining faithful to accepted disciplinary ideas. Third, she/he needs to manage the collective transformation of students’ beliefs and practices in accordance with constructivist norms. And finally, the teacher needs to confront issues of accountability with various stakeholders in the schoolroom community (Windschitl, 2002).

The four dimensions illustrate the complexity of educational change. Curricular reform in itself has been proven unsuccessful (Stocklmayer et al., 2010). Smith et al. (2007) argues that teachers need the training and information of the process of inquiry learning. Furthermore, according to Shavelson (1998), to obtain effective change, teachers’ concerns and points of view need to be addressed. This doctoral research will address this concern within its methodology, by giving voice to teachers and outreach practitioners points of view in relation to science education dilemmas.

Framed in the educational context, this section analysed teachers’ implementation of best practice, as advocated by curricular reform in science education. It concluded that teaching is still conducted in a teacher centred manner and analysed arguments in the literature that explain this reluctance. The next section explores the particular case of primary level science.

2.2.3.1 Primary level science, a particular case

Curricular reforms are acknowledging the increasing importance of primary education in terms of supporting progressive change in science education. The final years of primary level are highlighted as a key time for the school to motivate students towards a career in science (European Commission, 2007; Osborne et al., 2008). This is especially relevant in countries that have eight years of primary level, such as Ireland. In Ireland the last two years of primary level comprise of a comprehensive curriculum of science, a spiral curriculum that cumulates from previous years (DES, 1999).

In spite of curricular efforts, reports from the UK, Australia and Ireland, for example, reveal a gap between the intended and actual student curricular experience (Australian Science, Technology and Engineering Council, 1997; HM Inspectors of Schools, 1999; National Research
Council, 1996; Varley et al., 2008). These reports indicate that primary level teachers reveal a reluctance towards science. Research indicates that many do not have the preparation, confidence or the belief that science should be one of the most relevant subjects of primary education (Avraamidou, 2013; Kim and Tan, 2011; Ramey-gassert et al., 1996). Mulholland and Wallace (2003), for instance, sustain that pre-service early childhood teachers see themselves as ‘non scientist’. Appleton (2006) concludes that primary level teachers have a lack of nature of science knowledge and Mulholland and Wallace (1996) state that primary level teachers have negative science experiences and skewed views of science. Further, Gess-Newsome (2001) mention that a large proportion of primary level teachers are reported to have inadequate preparation in and poor understanding of science. Science teaching is imposed on many primary level teachers who do not feel confident or favourably inclined to teach it. As such, this generates tension (Appleton, 2006).

In Australia, for example, the curriculum developers recognize the challenge of implementing a Science curriculum (Osborne et al., 2008). In several reports it is admitted that coherent science programmes in the primary cycle are still an exception (Australian Science, Technology and Engineering Council, 1997; Goodrum et al., 2001; Osborne et al., 2008), in spite of the fact that science has been part of the curriculum in primary schools in Australia for over forty years (Osborne et al., 2008). Therefore, the teaching of science at primary level has particular problems, even in countries where it is a reality for decades.

In Ireland, science was introduced as a subject in its own right at primary level in 2003, with ‘nature studies’ as its pre-cursor since the 1971 curriculum (INTO, 1998). Only 10% of Irish primary level teachers have science in their university degree (Eivers and Clerkin, 2013). Furthermore, up to 2008, Ireland was the only OECD country in which primary level teachers did not have mandatory science training (Burke, 2008). These facts have lead Dr. Ed Walsh, founding president of the University of Limerick, to call primary level a ‘disaster’ in terms of science teaching (Burke, 2008).

The curricular change in primary level, the difficulties teachers face in implementing these changes in relation to science education, and the relevance given to primary level as the key time to motivate students towards science, form the rationale behind why primary level has been chosen as the focus of this study.

2.3 Science outreach: A remedy for a broken system?

Section 2.2.1 of this Chapter demonstrated the concern of governments in relation to the inadequate supply of scientists to fill future jobs, and the overall decline in science interest. To address these concerns different institutions developed science outreach programmes (DSE, 2011; European Commission, 2007; SFI, 2014b). This section starts by describing the objectives that guide science outreach, concluding with the different activities developed within this practice.

2.3.1 Science Outreach in the Republic of Ireland

As discussed in section 2.2.1 there is a concern across Ireland and Europe in relation to student interest and performance in science. In response to this, science outreach programmes lie at the centre of the European Union’s policy to create an economy supported by science literate people who are interested in research and innovation (Davison et al., 2008). The 2007 European Commission Report advocates that science outreach can accelerate the pace of change in science education:
Community support can be instrumental, not only in accelerating the pace of change, but also in enriching the newly developed techniques. The participation of all stakeholders, including experts of science education, teachers, students, parents, scientists, engineers and their organizations, including schools, teacher and parent organizations, universities, research institutes, Science museums, Science centres, firms and local authorities is a key factor for the success (European Commission, 2007, p.13).

The Rocard Report, as seen from the quote above, acknowledges that European Union funds should go to science outreach programmes that aim to create partnerships between formal and informal education stakeholders. It is the expert’s belief that these partnerships will, in the end, increase the number of students interested in science careers. This document, from the European commission has influenced policy in several European countries, such as Ireland (ALLEA, 2012).

In Ireland, Science Foundation Ireland (SFI), a state agency, is the primary investor in scientific research (SFI, 2014a). SFI’s mission is to invest “in academic researchers and research teams who are most likely to generate new knowledge, leading edge technologies and competitive enterprises in the fields of science and engineering” (SFI, 2008, p.2). As the primary financier in scientific research, SFI is strongly invested in science outreach programmes (SFI, 2014a). SFI has a specific programme for science outreach, SFI Discover programme. SFI Discover Programme is described as an auxiliary instrument to education. One of its central objectives is to support and develop the education and outreach sector (SFI, 2014a). Furthermore, it aims to increase the number of students following a science career. The strategy SFI Smart Futures 2014-2017, launched by the Irish government, focuses on this aim (SFI, 2014b). Its objective is to increase the uptake of science in second and third level by 10%. The specific steps of the strategy are described in figure 2.4.

Figure 2.4 Plan of the Smart Futures Strategy 2014-2017

<table>
<thead>
<tr>
<th>SFI Smart Futures Strategy 2014-2017 (SFI, 2014b)</th>
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<tbody>
<tr>
<td>- Build a database of volunteers to deliver STEM career advice to all secondary schools throughout the country by training for over 450 volunteers from STEM industries and SFI Research Centres by 2016;</td>
</tr>
<tr>
<td>- Offer industry opportunities to participate in more student outreach activities;</td>
</tr>
<tr>
<td>- Highlight exciting career opportunities in industry to help challenge stereotypes associated with people who work in STEM;</td>
</tr>
<tr>
<td>- Support students and parents in decision making related to STEM careers and further study.</td>
</tr>
<tr>
<td>- Monitor targets for increased participation by industry, increased numbers of students and schools involved, increased numbers of careers roadshows.</td>
</tr>
</tbody>
</table>

According to this strategy, SFI is going to organize visits by volunteer research staff to schools in order to showcase their research, discuss more general science issues and promote careers in science (SFI, 2014b). volunteer scientists to promote science interest and careers in classrooms. Research by Bell et al., (2003) has shown that having scientists working with teachers can improve teachers’ knowledge about the processes of scientific inquiry.

SFI has a specific programme for science outreach at primary level, Discover Primary Science (DPSM). SFI (2014a) considers it a flagship programme. DPSM (2012) provides resources for teachers and students to develop inquiry learning activities. Furthermore it provides training for primary level teachers. In the training that takes part in different discover science centres, teachers receive an activity pack (DPSM, 2014). The pack consists of 37 science activities that connect to the skills and strands of the Primary Science Curriculum. It also includes guidelines for teachers, activity notes,
scientific background information on the content and links to the primary science curriculum strand units and skills (DPSM, 2014). The DPSM outreach programme aims specifically to help teachers develop the Irish primary science curriculum. The DPSM outreach programme will be further discussed in Chapter six and seven because specific activities of DPSM are part of the methods developed for this study.

Engineers Ireland is another agency that supports science outreach programmes in Ireland. Engineers Ireland is the institute that represents engineering professionals in Ireland. Engineers Ireland sponsors the programme STEPS to Engineering that “encourages primary and post-primary students to explore the world of science, technology, engineering and mathematics while also promoting engineering as a career choice” (STEPS, 2014, para.1). The STEPS to Engineering programme goals are described in figure 2.5 below.

Figure 2.5 Goals of the STEPS to Engineering programme, adapted from STEPS (2014)

<table>
<thead>
<tr>
<th>STEPS to Engineering goals</th>
</tr>
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<tbody>
<tr>
<td>- Encouraging a positive attitude towards science, technology, engineering and mathematics</td>
</tr>
<tr>
<td>- Introducing to students the relevance of science, engineering technology and mathematics to industry and everyday life</td>
</tr>
<tr>
<td>- Raising a positive awareness and understanding of engineering as a career choice</td>
</tr>
<tr>
<td>- Promoting a greater understanding of the role and contribution of engineering in society</td>
</tr>
<tr>
<td>- Highlighting the advantages, diversity, opportunities and excellent rewards offered by a career in engineering</td>
</tr>
</tbody>
</table>

Engineers Ireland (2011) recognizes that quality science education is the most important factor to increase the number of students opting for careers in science. Furthermore, Engineers Ireland criticizes the actual situation of science education. Engineers Ireland (2011, para. 3) stated that “the old education system, particularly with regard to Maths, Science and technology, is no longer fit for purpose”. Consequently, Engineers Ireland targets science education. The programme ‘STEPS to Engineering’ aims to expand the science education curriculum. Specifically, it is interested in developing inquiry learning activities and concepts related to engineering and Mathematics. Engineers Ireland’s objective is to increase the interest in Engineering and to promote careers in the field, as visible in figure 2.7. Its objectives are more subject specific, when compared to SFI. Engineers Ireland (STEPS, 2014) is focused on concepts of mathematics and engineering and on the promotion of engineering careers.

In Ireland, the third level institutions and other government sponsored organizations are the major contributors of science outreach and they are primarily funded through SFI (Davison et al., 2008). Nevertheless, private enterprises are also relevant promoters of science outreach initiatives (Abbott Ireland, 2011; CEIA, 2012). As mentioned above, the Smart Futures Initiative (SFI, 2014b) wants to integrate these private outreach initiatives.

From the reports analysed, it is clear that stakeholders envision a relevant role for science outreach in engaging students with science. It is their belief that science outreach can accelerate change in science education (European Commission, 2007). The different stakeholders aim to bring more inquiry activities to schools through volunteer scientists (DPSM 2012; NSF, 2011; STEPS, 2014). Furthermore, the different stakeholders want to increase the interest in science and science careers. Nevertheless, these are broad objectives and to better understand science outreach, it is important to analyse programme objectives and practices in more detail.
2.3.2. Science outreach objectives: From education to vocation, where does it fit?

The previous section illustrates the way leading founders of science outreach frame their objectives. The objectives which they frame naturally seem to fall into two categories, educational and vocational. For example, studies by Crane et al. (1994), although not defined into these two categories also rather naturally fall into them. Crane et al. (1994) carried out an extensive review of science outreach and classified the objectives of science outreach into experience, performance, literacy, love of science, confidence that one can do science, progress towards a career in science and equality in science. In reflecting on the founders above, the author also felt that these objectives could be further classified into two categories, educational and vocational, and as such is presenting the research into these two categories. The educational objectives relate to the need to change the way science is taught in schools and include experience, performance and literacy. Vocational objectives relate to those that aim to attract students into science careers and include love of science, confidence that one can do science, progress towards a career in science and equality in science. In addition to these two broad objectives, different science outreach programmes list additional and/or related goals. A clearer understanding of these objectives is central to comprehending the problems faced by science outreach. Therefore, the different types of objectives presented by science outreach programmes are now analysed in detail. This analysis looks specifically at reports of outreach programs because it is often that only in these reports that the objectives are stated. The analysis starts with the educational objectives.

2.3.2.1 Educational objectives

Educational objectives are “explicit formulations of the ways in which students are expected to be changed by the educative processes” (Bloom, 1956 p.26). In other words, educational objectives represent what is required for students to learn (Anderson et al., 2001). Science outreach programmes list educational objectives within their reports, which range from introducing new concepts (DeWaters and Powers, 2009) to developing inquiry skills through hands on activities (Slezak et al., 2010) and increasing scientific literacy (Duncan et al., 2010). A common point is that they all have the objective ‘to enhance students’ scientific education’. The educational objectives can be subdivided into different categories, as figure 2.6 illustrates (Crane et al., 1994).

Figure 2.6 Educational objectives of science outreach

<table>
<thead>
<tr>
<th>Educational Objectives of Science Outreach (adapted from Crane, 1994)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experience</td>
</tr>
<tr>
<td>Performance</td>
</tr>
<tr>
<td>Literacy</td>
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</table>

The basis for and importance of each of these educational objectives is discussed as follows.

Experience

Experience is the most common objectives of science outreach programmes (Crumbly and Garcia-Otero, 2001; Girls Inc, 2011; Jeffers et al., 2004; Kimmel and Rockland, 2002; Lyons and Ebert, 2005). Experience objectives are a response to the documented discrepancy between
recommendations for inquiry learning approaches and the prevalence of teacher *top down* communication (Crane et al., 1994). Katz's (1996, p.33) science outreach project ‘Hands on Outreach’ has experience listed as a clear objective:

As children were not getting practical, hands-on experience with scientific material and scientific concepts in school, they needed this experience out of school and an organization was created expressively to provide the missing opportunity.

In other words, Katz (1996) believes that their outreach project was needed to provide the opportunity for hands on activities for students, as they were not part of their formal education. This argument is shared by a great number of science outreach programmes (Crane et al., 1994; Jeffers, 2004).

**Performance**

Some science outreach programmes emphasize high achievement in science as a goal (Crane et al., 1994). The level of success for these programmes is measured by the students’ performance in science. Two types of performance objectives are identified in the literature. Some programmes aim to increase students’ performance in skills required for processing science (Wally et al., 2005). Wally et al. (2005, p.1490) refer to their chemistry outreach project that aimed for students to develop “scientific investigations and design, conduct, communicate about, and evaluate such investigations”. Other programmes promote an improved knowledge of science for students (Frazier and Hodgetts, 1991). Frazier and Hodgetts’s (1991) science outreach programme offered a helpline for students’ who had doubts in relation to the science curriculum. In spite of its differences, all of these science outreach programmes want to increase student performance in science.

**Literacy**

Some science outreach programs were developed to introduce new science concepts or in response to concepts that were poorly assimilated in school (Crane et al., 1994). Duncan et al.’s (2010) science outreach programme aims to introduce the concept of nanotechnology to primary level students, a concept that is not part of the students’ science curriculum. There are also common objectives in outreach programs which promote the re-learning of concepts that are perceived by outreach developers as poorly assimilated by students (Munn et al., 1999). Munn et al.’s (1999, p. 597) outreach project in genomics provides “accurate and current information about genomics” to students, since they perceived problems in the teaching of genetics in schools.

**Educational objectives: a remedy for science education**

Science outreach programmes with educational objectives share a common belief and goal. As described, the developers of science outreach programmes believe that science education is flawed. Their goal is to try and correct the flaws through their programmes. They aim to solve some of the issues of science education. According to the NeuroScience Editor (2009):
Recently, many more scientists have become involved in attempts to improve public science education. Programmes designed either to provide basic Science content and creative Science teaching tools for teachers or to encourage scientists to form partnerships with their local schools have mushroomed.” (NeuroScience Editor, 2009a, p.1)

The NeuroScience Editor’s point is that scientists are now urged to help formal science education. However, this approach raises doubts. The NeuroScience Editor (2009), himself, writes:

Sending in scientists to educate these teachers' classes is unlikely to be the solution—scientists, no matter how enthusiastic, just cannot be good replacements for trained teachers in the classroom. Many have little idea of what goes on in an average Science class or how the curricula are regulated, and they do not have the skills to effectively educate K–12 students, especially those who are struggling with basic reading and writing skills or with social issues outside the classroom.” (NeuroScience Editor, 2009, p 1)

The essence of the NeuroScience editor’s (2009) argument is that scientists don’t have the preparation to bring the desired change to science education. This endangers education objectives of science outreach, as scientists do not have experience or professional development in working with primary and second level students. As such, some actions have been taken to mitigate these concerns. One example is the ReSciPE project. Thiry et al. (2008) state:

Little research evidence exists to help practitioners understand scientists’ education and outreach interests, beliefs, and motivations, and the barriers that must be addressed to involve them effectively. The ReSciPE Project (Resources for Scientists in Partnership with Education) has offered professional development workshops and resources to a wide audience of working scientists who undertake individual or institutional education and outreach activities (Thiry et al., 2008, p 236).

In the ReSciPE project, based in the USA, scientists are trained to deliver science outreach initiatives to primary and second level students. This project recognizes the lack of formal education/curricular background that scientists have, and through workshops, offers them professional development. It comes as a response to scientists’ concern in relation to this lack of preparation. As evident in section 2.3.1, the new outreach programme from SFI also follows this route. It offers outreach training to scientists. This half a day workshop starts with an opening presentation that describes inquiry and summaries evidence from education research that supports inquiry methods. Then, using hands-on activities, scientists see how students can learn though inquiry (Thiry et al., 2008).

As shown in this section, educational objectives are recurrent in science outreach programmes. Educational objectives stem from problems perceived by science outreach in science education. Educational objectives exist to try and remediate these problems. Nonetheless, concerns about the role of science outreach in educational objectives are visible in the literature. It is argued that vocational objectives might be more suitable in science outreach programmes. The next section analyses vocational objectives.
2.3.2.2 Vocational objectives

The reports analysed in section 2.3.1 state that science outreach can increase the vocational motivation of students. The end objective is to attract students into a science degree and career. Accordingly, the vocational objectives of science outreach relate to programmes that openly aim to increase the number of students following post-secondary scientific education.

Vocational decision theories connected to social learning focus on the way students interact with their environment in making a career decision (Portnoi, 2009). For instance, Krumboltz (1996) presents a social learning theory of career decision making. The theory assumes that individuals are actively involved in the decision making process (Portnoi, 2009). Krumboltz (1996) states that factors such as genetics, environmental conditions and learning experiences play a significant role in the decision making process. Expectancy-value theory is another approach that analyses young people’s decision making (Wigfield and Eccles, 2000). According to this theory, ‘individuals’ choice, persistence, and performance can be explained by their beliefs about how well they will do on the activity and the extent to which they value the activity’ (p. 68). The motivation for an educational choice consists thus of two main aspects: the students’ expectation of success and the value that the students attribute to this particular option (Boe et al., 2011).

Therefore, vocational choice is a complex task, and influencing a student’s decision is not a straightforward educational process (Portnoi, 2009).

Further, Regan and De Witt (2015, p. 79) in a comprehensive literature review of the facts that influence science, technology engineering and maths conclude that:

research conducted over the years has consistently identified a number of factors related to school (pedagogy/teaching, curriculum, type of school, teachers), family background (parental support and resources), and individual characteristics (age, attainment and, critically, gender), as well as widely-held images of science and scientists, as influencing STEM choice.

In spite of its complexity several outreach programmes openly incorporate vocational objectives, as represented in figure 2.7.

Figure 2.7 Vocational objectives in Science outreach

<table>
<thead>
<tr>
<th>(Crumbly and Garcia-Otero, 2001)</th>
<th>(Sugg and Fishele, 2008)</th>
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<tr>
<td><em>(Mathematics, Science, and Engineering Academy (MSEA) is a pre-college outreach programme implemented by the Fort Valley State University (FVSU) [USA] Cooperative Developmental Energy Programme (CDEP) since 1993. The goal of the CDEP's MSEA programme is to create a continuous pipeline of minority and female students, from eighth grade through Ph.D., majoring in mathematics, Science, or Engineering,)</em> p.1</td>
<td><em>(“Through a number of community outreach activities, interventions at the grade school level through High School provide ample opportunity to strengthen the S&amp;F pipeline at these early stages. Active participation with Universities through board participation, partnerships, internships, and career fair participation provide the critical link between the qualified entry level workforce and the needed defence sector jobs.”)</em> p. 3</td>
</tr>
</tbody>
</table>

The science outreach programmes highlighted in figure 2.9 are based on the pipeline model. This model was introduced in policy documents in the 1980’s (Metcalf, 2010). It was introduced to address the concerns of the aforementioned NSF Report: ‘A nation at risk’, analysed in section 2.3.1. The model describes the linear sequence of steps necessary to become a scientist or an engineer.
Motivated and skilled students leave secondary school, choose science fields in their higher education and follow science careers. The pipeline does not represent educational objectives per se, nor the way students learn and/or do science. The goal is solely to encourage students to follow science courses and careers.

The pipeline model is criticized due to its linearity and the portrayal of people as a passive pipeline ‘flow’ (Xie and Shauman, 2003). Science outreach programmes that use this model rarely consider varied career paths and multiple ways of entering and re-entering science. Moreover, they tend to homogenize and oversimplify the complex ways that people learn, work and identify themselves (Metcalf, 2010). In spite of its flaws, the model has survived until now and it is still used by science outreach programmes with vocational objectives (Ragusa et al., 2008; Sugg et al., 2009).

The vocational objectives can be subdivided into four categories, as figure 2.8 illustrates.

**Figure 2.8 Types of vocational objectives**

<table>
<thead>
<tr>
<th>Vocational Objectives of Science Outreach (adapted from Crane, 1994)</th>
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<tr>
<td><strong>Love of Science;</strong></td>
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<tr>
<td><strong>Confidence that one can do Science;</strong></td>
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<tr>
<td><strong>Progress towards a career in Science;</strong></td>
</tr>
<tr>
<td><strong>Equality in Science.</strong></td>
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Vocational objectives differentiate the ideas, sometimes antagonistic, that guide different science outreach projects. The four types of vocational objectives are now analysed in detail. Examples of different science outreach projects are reviewed to better exemplify the vocational objectives.

**Love of Science**

Some science outreach programmes follow the view that students will stay in the scientific pipeline if you provide them with positive opportunities to engage with science (Crane et al., 1994). Therefore, the objective of these programmes is to provide the students with enjoyable experiences. Throughout the years, a considerable number of reports state as an objective: show science is fun (Boehlert, 2007; Botte, et al., 2008, Silverstein, 2005). Silverstein’s (2005) outreach project is a quiz game based on a TV show. It specifically aims to show that science is fun and the authors state they want the children to have a good time. Similarly, Botte et al., (2008) also intend to show science as being fun and interesting. In this case through “fun, unique and interactive birthday parties” (p.2).

Programmes with these types of objectives assume there is a strong connection between liking science and engage with it in the future as a career (Crane et al., 1994). As the study of De Witt et al. (2011) has suggested, this is a problematic connection. According to the authors, children can report enjoying science and still choose not to study it at a higher level. De Witt et al (2011) concluded that constructions of science and identity are circumscribed by social class, ethnicity, and gender. Their research suggest that enjoying science is not enough, because children reported enjoying doing science but do not identify themselves as future scientists in later years.

**Confidence that one can do Science**

‘Confidence that one can do science’ objectives take a somewhat opposite view from the ‘Science is fun’ objectives. Programmes with the ‘Confidence that one can do science’ objective acknowledge that following science demands effort and commitment. Furthermore, it is believed that students need to be empowered to follow science (Crane et al., 1994).
Programmes with this objective have two recurrent strategies. In one, developers showcase role models of successful scientists that overcame challenges, as it is the case of Pruitt et al., (2010) engineering outreach. Another common strategy is providing mentors that follow students through projects or even through school years (Winkleby et al., 2009). Winkleby et al.’s (2009) medical science outreach programme selects students and mentors them throughout secondary school. These programmes are designed to empower students and help their progress in science.

Within programmes with this objective exists a debate in relation to the target audience. On one hand, there is the view that everyone can do science. Therefore, programmes should be open to everyone and target students independent of their initial ability (Digas et al., 2007). On the other hand, other programmes see science as a field that requires exceptional and strongly committed students and as such view that, science outreach programmes should focus on these students (Rosendahl, 1992). This conflicting view reveals a tension between which group to target. A similar tension also exists within the last two objectives: ‘progress towards a career in science’ and ‘equality’.

**Progress towards a career in Science**

Some science outreach programmes have the expectation that some of the participants will definitely decide on science as a career choice (Crane et al., 1994). Programmes of this type want to recruit students to their courses, as this quote exemplifies:

Currently, there is a shortage of qualified engineers, therefore; improving recruitment efforts is an urgent priority at engineering educational institutions. In the College of Engineering (CCE) at San Jose State University (SJSU) a pilot project on student recruitment is being tested using innovative techniques for increasing the awareness level of high school students on engineering careers (Yates et al., 1999, p. 9).

The SJSU initiative is a clear recruitment initiative that wants to improve the number of students enrolled in their engineering courses.

Another example is Huggard and McGoldrick (2006) computer science outreach programme:

The *raison-d’être* of the event is self-evident – it is a recruitment initiative that aims to increase student intake into our undergraduate degree programmes. Firstly, we considered the gender balance of our existing student cohort. This shows a significant male bias – increasingly so over the past five years. Thus, our event had to be capable of strongly appealing to, and engaging with, male second level students with a predisposition towards the disciplines of Computer Science. Secondly, as ever, we wish to increase our intake of female undergraduates so the event should specifically target this student grouping also (Huggard and Mc Goldrick, 2006, p. 4).

Basically, what Huggard and McGoldrick (2006) are stating is that their programme targets second level students with the objective of increasing the student intake in the computer science degree of the university. It is a recruitment initiative aimed at the students with a pre-disposition towards computer science. Although they also state the program wants to increase the intake of female
students, this seems a secondary objective. The last objective, equality in science, reveals a contradictory stance.

**Equality in Science**

Projects that aim for equality target students that are not usually predisposed towards science. The programmes are characterized by having strong social concerns and objectives, as the quotes in figure 2.9 illustrate.

**Figure 2.9 Equality objectives in Science Outreach**

<table>
<thead>
<tr>
<th>(Winkleby et al., 2009)</th>
<th>(Craig and Horton, 2009)</th>
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<tr>
<td>&quot;Despite decades of precollege science outreach programmes, African Americans, Latinos, and Native Americans remain critically underrepresented in Science and health professions (...) This report describes college and career outcomes among graduates of the Stanford Medical Youth Science Programme (SMYSP), a 5-week summer residential programme for low-income high school students.&quot;</td>
<td>&quot;In order to address the under-representation of women in Computer Science, we have created a programme for middle-school girls that specifically aim to change their attitudes about CS and encourage them to see it as a potential career.&quot;</td>
</tr>
<tr>
<td>p. 535</td>
<td>p. 221</td>
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The essence of Winkleby’s (2009) and Craig and Horton’s (2009) argument is that science outreach should bring the under-represented to science. To achieve this, science outreach programmes that target minorities and female students were developed.

Science outreach programmes’ equality objectives are criticized by Bouville (2008) and Metcalf (2010). Bouville (2008) argues that “one cannot try to ‘recruit’ as many female students as possible while claiming to help them choose more freely” (p. 279). His argument is that outreach should not influence students. Bouville (2008) contends that students must be allowed to graduate in a field congruent with their desires and abilities. Townley (2009) challenges the views of Bouville. First, the author argues that there is no evidence that outreach programs try to coerce female students into science. Townley (2009) contends that these outreach programmes provide information (experience, role models and the like) to support an informed decision (p. 296). Finally, Townley (2009) argues that the historical exclusion of women in science makes it mandatory that science fields show that they no longer practice unfair treatment. Another criticism in relation to equality objectives comes from Metcalf (2010). The author criticizes the definitions of minority and gender used in science outreach. For example, some studies compare in an inadequate way, males and females in general, and whites and various racial groups (Metcalf, 2010). They tend to oversimplify the issue, not considering the multiple and complex features involved in those categorizations.

In spite of some criticisms, a great number of reports argue the need of initiatives specifically directed to women and minorities (Craig and Horton, 2009; NSF, 2011; Pierre and Christian, 2002; Sivilotti and Demirbas, 2003). The argument is that the current environment is not neutral regarding the underrepresented in science. Therefore, these programmes are needed.

**Vocational objectives, who to target?**

Vocational objectives reveal a division between science outreach programmes. On one hand, there are programmes that aim to bring female students and minorities to science. On the
other hand we have programmes that target students already interested in science. These are
decisions that developers of science outreach face. One should not look at them as right or wrong,
but as complementary and situation focused. Adequate target audiences may be different for
different science outreach programmes. What is lacking, in a great number of published reports, is
a reasoned statement of the decision on who to target. The statements are usually based on vague
justifications instead of hard facts (Bouville, 2008; Xie and Shauman, 2003).

This section analysed the four types of vocational objectives of science outreach (illustrated
in figure 2.8). It was visible during the discussion that vocational objectives come with differing
views, which may lead to tension.

After analysing and discussing the different types of objectives presented by science
outreach programmes, the next section looks at the resulting practice. The different types of
programmes offered by science outreach are described.

2.3.3 Science Outreach Practices

As previously determined in section 2.3.1, government institutions in Europe and Ireland
encourage and support science outreach programmes with vocational and educational objectives.
These objectives were subsequently discussed in section 2.3.2. Several types of science outreach
programmes are developed in order to meet both the vocational and educational objectives. By
reviewing numerous outreach programmes, Crane et al. (1994) and Jeffers et al. (2004) identified
several common themes in approaches towards science outreach. Crane et al. (1994) classify science
outreach programmes as three types. Jeffers et al. (2004) divides physics and chemistry outreach
programmes into five types. Both classifications are illustrated in figure 2.10.

Figure 2.10 Classification of science outreach programmes

<table>
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<tbody>
<tr>
<td>Discovery programmes</td>
<td>Develop classroom material including Web-based resources;</td>
</tr>
<tr>
<td></td>
<td>Conduct outreach activities on the college campus;</td>
</tr>
<tr>
<td>Science camps</td>
<td>Conduct outreach activities at the K–12 school;</td>
</tr>
<tr>
<td></td>
<td>Conduct or sponsor science contests;</td>
</tr>
<tr>
<td>Career Programmes</td>
<td>Teacher involvement.</td>
</tr>
</tbody>
</table>

Crane et al.’s (1994) classification was one of the first attempts at classifying science
outreach programmes. It describes three types of programme, excluding numerous types that are
now common. By contrast, Jeffers et al.’s (2004) classification addresses many more types of
programme. The limitation of Jeffers et al.’s (2004) classification is that it is specific to physics and
chemistry outreach initiatives. In order to provide a more complete picture of the current array of
practices in science outreach, this thesis presents an updated classification of science outreach
programmes. The classification presented in this section builds on the classification of Jeffers et al.
programmes in general. One more type, cooperative projects, is added to Jeffers et al.’s
classification, following a detailed review of current science outreach practice. For this classification
numerous science outreach programmes were reviewed. Examples from this review are given
below, to illustrate the different approaches.
2.3.3.1 Developing classroom material including web based resources

The review of science outreach programmes found that developing materials for primary and second level classrooms is a common approach within outreach. These approaches attempt to expose students and teachers to inquiry activities (Jeffers et al., 2004). Different types of approaches are developed:

- the offer of hands on inquiry based activities that students or teachers can use as a once-off activity (CSIRO, 2011; DSE, 2011). For instance, DSE (2011) offers inquiry activities in their website that teachers and students can use;
- very structured curriculum units aimed to replace or enhance the normal science curriculum (Bruder and Wedeward, 2003; Mooney and Laubach, 2002). In this case, the developer’s objective is that the units are used for a longer period of time. Mooney and Laubach (2002) Adventure Engineering programme developed an inquiry curriculum that aims to replace three weeks of traditional curriculum.

These initiatives have the potential to reach larger audiences, as the materials are published online. Nevertheless, feedback mechanisms need to be present. Without systematic evaluation, the developers cannot assure that the materials are being used as intended or even if they are being used at all (Jeffers et al., 2004).

2.3.3.2 Outreach activities on the college campus

Science outreach programmes conducted in universities are an additional way to introduce students to state of the art science and to real scientists (Jeffers et al., 2004). The review of a series of college science outreach programmes revealed that they utilise a range of different activities and methods. As figure 2.11 shows, the programmes can have very specific educational objectives (Luehmann and Markowitz, 2007; NUIG, 2011). On the other hand the activities can be recruitment activities with vocational objectives (Huggard and Mc Goldrick, 2006; Lopez-Martin, 2010).

Figure 2.11 Different types of outreach activities on college campus

<table>
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<tr>
<th>Practices with educational objectives</th>
<th>Practices with Vocational Objectives</th>
</tr>
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<tbody>
<tr>
<td>Stepping Up (NUIG, 2011).</td>
<td>Computers Science Department of the University College of Dublin (Huggard and Mc Goldrick, 2006).</td>
</tr>
<tr>
<td>This programme is designed to facilitate students’ transition from primary to secondary school emphasizing on mathematics education;</td>
<td>It is an initiative aimed at transition year students. The University brands it as “a recruitment initiative”. In it, the students “interacted with staff from high-profile technology companies and gained an insight into their latest innovations and experience daily life on a University campus” (p.47)</td>
</tr>
<tr>
<td>University of Rochester’s Life Sciences Learning Center enrichment programme (Luehmann and Markowitz, 2007).</td>
<td>College of Engineering of University of Navarra’s (Lopez-Martin, 2010).</td>
</tr>
<tr>
<td>In this programme second level students are taught curricular units. The units focus on supporting students’ understanding of concepts and investigative skills related to recombinant DNA, genetics, cell biology, and environmental health</td>
<td>In this initiative, “just one month before students will make their choice of a university degree, the College of Engineering organizes a one-day visit to the engineering facilities of the university campus” (p. 46). During the tour, the degrees are thoroughly explained to students and they take part in hands on experiments. One week after, the students have follow up workshops. In this workshop they receive detailed information about the degree they are interested in and its employment opportunities</td>
</tr>
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These are examples of the two extremes of the continuum of activities that exist in ‘out of school’ contexts. On one hand, they can be practices with strong educational objectives that can assist students in their science education (NUIG, 2011). On the other, programmes that want to
attract students to specific science courses and that have reportedly obtained success in doing so (Lopez-Martin, 2010).

Luehmann and Markowitz’s (2007) findings indicate that these teachers came to identify and value out-of-school enrichment programmes for their impact on students’ motivation and identity development.

2.3.3.3 Outreach practices in primary and secondary schools

Taking science materials to schools is considered the quickest and most efficient way to reach a considerable number of students and introduce them to science (Jeffers et al., 2004). The review of science outreach programmes found that a common approach is to send undergraduate or graduate students to primary and second level schools. In the classroom, they develop hands-on/inquiry based activities. Once again different types were found:

- One-off initiatives such as chemistry demonstrations carried out by graduate students of the Midwestern state University Outreach programme (Voegel et al., 2004) or the extensive chemical magic show Promotion of Chemistry in Schools Project that reached directly 8500 students in 67 schools with a total of 192 shows in Ireland (Regan, 2009);
- After school enrichment programs that follow the same set of students for the four years of their post-primary education. One example is the Computer Sciences programme from the Harvey Mudd College (Dodds and Karp, 2006). This programme offers enrichment after school sessions and follows students for years.

There are also different and innovative ways in which science is being brought to the classroom, connecting it with art. Examples of this are:

- Fusion Science Theatre that uses ‘theatre to engage children in Science’ (Kerby et al., 2010);
- the outreach programme from Duncan et al. (2010) that uses glass artistry to engage students with nanotechnology.

Fusion Science Theatre and the Nanotechnology science outreach programmes are recent attempts to diversify the way in which science outreach reaches schools. The majority of science outreach programmes in schools, involve hands on inquiry driven activities (Jeffers et al., 2004). Laursen et al. (2007, p.49) report that in this type of science outreach interventions “students are engaged in authentic, hands-on activities that generate interest in science and new views of science and scientists”.

2.3.3.4 Science contests

This review found that several universities and other institutions are involved in science contests. Science contests can take various forms:

- Debates, as the Debate Science Issues nationwide Irish Initiative. It involves secondary school students and ends on a final in the Science Gallery in the countries’ capital. In this event “students engage in debate on the cultural, societal and ethical implications of advances in biomedical science” (DSI, 2011, para. 1).
- Research proposals, as the Viksu initiative from the Finish Science Academy for senior secondary students. For this contest, students write an independent scientific research project. This is a highly competitive initiative, as the prizes are far from being the usual
trophy. They involve a monetary prize, a bursary, and the possibility of entrance into the University, without the need to do exams. It is a method of developing science outreach in which students have an immediate reward for their work (AF, 2011).

These are two examples of nationwide initiatives. In addition, there are many more examples of smaller scale science contests sponsored by universities. Science fairs are the most common example (Albers et al., 2010; Torres et al., 1997; Valdes et al., 2010). The science fairs’ objective is to reward and showcase cooperative hands on activities carried out by the students.

### 2.3.3.5 Cooperative projects

This review revealed that many students are now taking part in cooperative projects where they collaborate in investigations that the scientists themselves are working on. An example is the French-German initiative Aquarius Xenopus (Horn and Dournon, 2007). In it, students work together with scientists from the International Space Agency. The students studied the swimming behaviour of *Xenopus* tadpoles on ground and on space (Horn and Dournon, 2007). Initiatives of this kind have the advantage of having students actually collaborating with scientists in scientific work. Results showed that the responsibility increased the students’ motivation (Horn and Dournon, 2007). The potential of having students collecting data and sharing it with scientists is being explored. Other examples are:

- NASA’s project S’Cool (Allner et al., 2010) in which students submit their cloud observation data for NASA scientists;
- the European project Greenwave (2014) in which students submit their data on biodiversity.

Cooperative projects are now becoming more common. In these type of projects, students need support and to feel connected with the scientific investigation. If this is not the case, there is a risk of it being portrayed as another school assignment (Horn and Dournon, 2007). The fact that the learning is removed, or somewhat removed from the classroom due to the collaborative element has potential for greater retention or meaningfulness.

### 2.3.3.6 Teacher involvement

These science outreach programs partner scientists with teachers. As stated by Zachary, et al., (2000):

The way science and math are taught critically affects their interest and later participation in science and engineering. If this is the case, then the responsibility falls primarily on the teaching profession. A report to the National Science Foundation recommends that colleges and universities employ science, mathematics, and engineering departments to work collaboratively with departments of education, the K-12 [primary and second level] sector, and the business world to improve the preparation of K-12 teacher (p. 1).

The developers of this type of outreach programmes want informed and motivated teachers that can excite and instil confidence in their students. They assume teachers lack practical knowledge of different science fields. Furthermore, they state teachers lack professional confidence. Therefore,
they offer programmes which provide this knowledge (Jeffers et al., 2004). The following quote from an in service teacher’s workshop provided by Engineering Universities illustrates this methodology:

The typical workshop involves instructing K–12 teachers about basic engineering concepts and examples, reinforcing this instruction with hands-on laboratory experiences and providing materials and resources for the teachers to share with their students when they return to the classroom. (Jeffers et al., 2004, p. 104)

In other words, the developers want to teach the teachers the science concepts and methods they believe the teachers lack.

2.3.4 The role of teachers in science outreach programs

As this section illustrated, the only type of science outreach programme that gives a relevant role to teachers is ‘teacher involvement’. The method followed by this type of science outreach programme resonates with the deficit model, discussed in Chapter one. Universities and other organizations that develop science outreach identify a ‘lack of knowledge’ on the part of teachers. Furthermore, they assume that the teachers’ practice will change because they are given information. The effectiveness of this type of reasoning is criticized. This is because it assumes that teaching the teacher may lead to a change in hers/his practice (Goulart, 2007; Windschitl, 2002). As, in the deficit model, it assumes that information alone leads to change in behaviour (Cullen et al., 2007; Davison et al., 2008). A reasoning of this kind oversimplifies the problem and endangers the potential for change.

Furthermore, the lack of a teacher’s insight in the other types of science outreach practices is criticized. Luehmann and Markowitz (2007) recognize that few science outreach studies focus on the valuable perspectives that could be provided with the teachers involved. This happens, in spite of the existence of a body of literature on the potential and benefits of science outreach. It is therefore necessary to invite teachers to be a part of science outreach, and incorporate them as partners.

2.4 Partnerships between Science Education and Science Outreach: The role of conceptual and pedagogical dilemmas and gaps Identified

This Chapter analyzed the current state of science education and science outreach policy documents and reports. A re-occurring gap was identified within the several reports analysed, as the need for a connection between science outreach and formal education. For this connection to be possible it is important to understand and compare the views that emerge from the two fields in relation to the types of educational and vocational objectives identified. Stocklmayer et al. (2010) presented the concept of a third space to illustrate the connections between science outreach and science education, as illustrated in figure 1.6 in Chapter one. According to Stocklmayer et al. (2010):

The informal educational sector, because of its diversity, is relatively immune to bureaucratization and hence to ossification. It is relatively free to assist in the provision of the worthwhile education by means of which young people become actively engaged in learning about Science. The scope of the informal sector must be exploited and its limitations overcome. It can provide a third space: a place within which the very
different and competing discourses of the school system and everyday world are reconciled (p. 20)

Stocklmayer et al. (2010) argue that change in science education does not seem achievable in the near future. Schools systems have shown repetitively that they resist it. Furthermore, the authors believe that outreach is free to provide a worthwhile education. Nevertheless, as the authors themselves write, this is a belief. A comparison between outreach and education is needed to fundament it. It is in this messy environment that science outreach may create the above mentioned third space.

Windschitl’s (2002) constructivist dilemmas offer a basis to compare outreach and education in this messy environment. As described and illustrated in figure 2.3, the author classified these dilemmas as conceptual, pedagogical, cultural and political dimensions. To compare both fields and understand the potential of third space, it is important to identify the constructivist dilemmas that are more relevant to both science outreach and science education. This study is based mainly on the conceptual and pedagogical dimensions. The reasons for the selection of these dimensions and the exclusion of the cultural and political dimensions are now presented.

The cultural dimension relates to the issues that arise in the school community whilst it reorganizes itself towards a constructivist science education. The dominant culture in the classroom is one in which students are expected to give the right answers instead of deeper thinking (Windschitl, 2002). Therefore, when presented with constructivist based activities, students tend to look for the right answer instead of taking time to explore the inquiry activity. Additionally, the ‘good educational’ classroom is still seen by teachers and parents as a quiet and orderly one (Oakes et al., 2000). This type of culture endangers the development of constructivist teaching and learning as it impairs students from having control of their own learning.

Science outreach does not have a direct role in the cultural dimension of constructivism within a school. Two arguments explain this. Firstly, 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 regularly. Secondly, when present in the classroom, science outreach is viewed as an informal activity. This informal nature allows outreach work not to suffer from the cultural constraints that formal educational work does (Stocklmayer et al., 2010). As science outreach is not a regular activity and has an informal nature, it does not have a direct role in the cultural dimension.

The political dimension also does not fall within the direct scope of science outreach. The political dimension is associated with pressures from stakeholders in the school community, pressures that may endanger constructivist learning. One of the leading pressures imposed by stakeholders on the teaching and learning environment is standardised assessment. Standardized tests assess student, teacher and school performance, and they are now dominating the educational agenda (Smerdon et al., 1999). These tests push teachers towards direct methods of instruction (Windschitl, 2002) since the traditional method of instruction is perceived as the best practice to prepare students for this type of test (Tobin and Tippins, 1993). Informal science experiences, which outreach offers to students, do not suffer from the type of pressures that science education does (Stocklmayer et al., 2010). In a sense, the informal nature and in-frequent activities of science outreach practices in schools is also a reason as to why they are also not directly impacted with pressure from stakeholders. Their time there is short, so their likelihood of being impacted by the political dimension of the school environment is minor. This type of pressure, exemplified by the standardized tests, does not directly influence the informal activities of science outreach. Therefore,
once again, the role of outreach practice is indirect in the specific issues that affect the political dimension of constructivism.

Although science outreach does not have a direct role in cultural and political dimensions, as discussed in the previous paragraphs, it influences them indirectly. The indirect influences exist because these dimensions should be viewed in an ecological way (Windschitl, 2002). The ecological view acknowledges that the four types are interconnected. Therefore, the work developed by science outreach will obviously influence in part, the cultural and political issues lived in school.

The conceptual and pedagogical dimensions of constructivism are relevant to both teachers and science outreach practitioners. The first deals with a teacher’s ability to make sense of the concepts that guide constructivism. For constructivist learning to occur in the classroom, teachers need a thorough understanding of constructivism. Without it, wholesome learning might not occur, even when developing activities that should foster constructivist learning, such as inquiry activities (Windschitl, 2002). Inquiry activities can be reduced to activities which are interesting and involve engaging activities, yet they may not lead to worthwhile learning (Prawat, 1992). Science outreach origins and practices direct us towards constructivism: hands on experiences for active engagement, inquiry learning experiences and the use of artefacts for open construction (Crane et al., 1994; Jeffers et al., 2004). Therefore, it is essential that both teachers and science outreach practitioners have understanding of the concepts that guide constructivism in terms of their effective role in facilitating student learning.

The pedagogical dimension represents the challenges 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 et al., 1994; Jeffers et al., 2004). However, designing learning experiences that foster constructivist objectives is one of the main purposes of science outreach practitioners. A review of the literature reveals a great number of examples of science outreach activities that enter the classroom with constructivist objectives (Crane et al., 1994). Furthermore, it is argued that science outreach programmes lack a structured pedagogical approach with clear methods and aims, as they rely for the most part on volunteers without educational background (Neuroscience Editor, 2009; Stocklmayer et al., 2010).

The conceptual and pedagogical dilemmas of constructivism are relevant to science education and science outreach. Therefore, they are useful concepts to compare science education and science outreach in order to achieve a comprehension of the third space. The third space defined here encompasses symbiotic partnerships between science education and outreach. Promoting interest in science and science careers within the third space is foreseen as more viable than without the sustainable partnerships.

Therefore, to define the constructivist dilemmas that will be used in this study, constructivism is discussed further and analysed in Chapter three. Moreover, because the views of teachers and of science outreach practitioners are compared through conceptual and pedagogical dilemmas, Chapter three explores the dialectic method that will allow this comparison to be achieved. Dialectics are a philosophical discipline that uses movements of contradiction between concepts as a vehicle to obtain new knowledge. Dialectics is then used to frame the conceptual and pedagogical dilemmas that guide this study.

2.5 Chapter summary

This Chapter discussed science outreach and science education. It started with the analyses of the current state of science education policies. It established that policy makers argue for a change
in science education that would enable more students to follow scientific career paths. Policy recommendations were reviewed in relation to how science education is implemented within the different curricula and it concluded that curricula argue for inquiry learning based on constructivist principles. Furthermore, it revealed that the Irish primary level curriculum also values a constructivist approach. The Irish Curriculum aligns with the reform movements, emphasizing inquiry, autonomous learning and creativity. Finally, teachers’ practice was discussed, drawing a comparison with what is recommended by curricular reform. It revealed that the traditional method is still a common practice and the rationale behind this was explored. Particular challenges in primary science education were also discussed that include lack of preparation and confidence of primary level educators to teach science and the fact that in Ireland, only 10% of primary level teachers had science in their degrees.

The second section of the Chapter described the practice of science outreach. First it analysed the array of organizations that fund and develop science outreach. The reports suggest that science outreach could be a catalyst for change in science education. Many organizations aim to bring outreach to schools though volunteer scientists. The Chapter continued by analysing the specific objectives and practices found within science outreach. Previous classifications of objectives and practices of science outreach were modified and enhanced through the analysis of current science outreach reports. It was visible from this analysis that the leading aim of the majority of initiatives is to bring more inquiry learning to students. At the same time developers want to attract students into science and science careers. The barriers that endanger these objectives were discussed throughout the section. They include the insufficient educational knowledge and experience scientists have in relation to primary and second level classrooms and science curricula. Furthermore, the lack of teachers’ perspectives in studies of science outreach was reported.

The final section of the Chapter emphasized the need for a greater connection between science outreach and science education and how constructivist dilemmas offer a basis to compare outreach and education in this messy environment.
Chapter Three: Dialectic and constructivist criteria for science education
3.1 Introduction

Constructivist theory and philosophy of learning provides the basis for reform in science education (Steffe and Gale, 1995). It offers a new perspective on how teaching and learning of science is portrayed (Windschitl, 2002). Science outreach objectives and methods are also influenced by constructivism, and as such, a constructivist approach to learning, which is lacking in science education teaching practice (National Research Council, 2011; OECD, 2010, McCoy et al., 2012). Constructivism is a theory of learning, not of teaching, which is conceptualized differently by different theorists (Stocklmayer et al., 2010). Furthermore, there is not a constructivist method of teaching. Different methods of teaching can produce acts of construction of knowledge. This is because constructing knowledge is part of how the mind operates. Therefore, constructivist pedagogy is more of a descriptor of instructional teaching methods. Criteria are needed to describe and compare teaching methods according to constructivism. Constructivism is a theory and philosophy of learning that several teaching methods can follow. A dialectic view of constructivism offers this solution. In dialectics, knowledge is a constructed synthesis which resolves contradiction between different views (Riegel, 1979). The use of dialectic dichotomies allows conceptual and methodological distinctions between the various models of teaching and curricula.

The initial section of this Chapter examines constructivism and dialectics. It starts by discussing constructivist views in science education. The second section analyses the dialectical method and its application to science education. It discusses dialectics, its origin and connection to constructivist epistemology, with particular reference to Piagetian constructivism. The second section continues by analysing Piagetian models of science education. The Chapter concludes with the presentation of the dialectical dichotomies relevant to this study, that allow for a comparison of science education concepts and pedagogies.

3.2 Constructivist views in science education

Constructivism has had a strong influence on educational practice over the last three decades (Steffe and Gale, 1995). A search in an academic database with the key words education and constructivism returns more than 2000 references, revealing that there has been extensive research carried out about constructivism in education.

Constructivism’s importance in science education and outreach is well supported in the literature. Nonetheless, its popularity is also its main threat. Many fragmented teaching strategies based on superficial understandings have distorted the concept of constructivist teaching (Windschitl, 2002). Joyce-Moniz (1988) states that constructivism has many components and cannot be defined by fragmented strategies. It is the combination of the different components that defines constructivism. The different components argued by Joyce-Moniz (1988) are now discussed. Firstly, constructivism is not justified because the learner constructs knowledge, or because learning is a progressive construction of knowledge. This is a true but tautological justification. Likewise, Joyce-Moniz (1988) argues that it is not sufficient to state that constructivism is an epistemology in which the person acquires knowledge from experience. This justification does not separate constructivism from all the other pro-Aristotelian models, such as the cognitive and the information-processing ones. Defining it as a methodological tool for helping the learner to take the initiative and to manage the process of learning is correct. Nonetheless, it does not distinguish constructivism from other models that promote individual initiative and autonomy in learning. Finally, it cannot be characterized only by having the teacher incentivize and facilitate the learner’s activity in class. It
reflects the main practice of constructive teaching, but it does not differentiate it from many other science education models. Constructivism is the combination of all of these components.

In summary, constructivism emphasizes the progressive construction of knowledge, which is obtained from experience (Piaget and Inhelder, 1969). Consequently, constructivist teaching and learning is a methodological tool for helping the learner to take the initiative and to manage the process of learning (Joyce-Moniz, 1988). Moreover, in constructivist teaching and learning the teacher incentivizes and facilitates the learner’s activity (Piaget and Inhelder, 1969).

There have been various types of constructivism discussed in the literature, such as social constructivism (Ernest, 1998); radical constructivism (Von Glasersfeld, 1995); cognitive constructivism (Piaget and Inhelder, 1969); information processing constructivism (Perkins, 1992) and socio-cultural approaches to mediated action (Steffe and Gale, 1995). Although there are an extensive variety of constructivist models, this study is grounded in two constructivist theories: cognitive constructivism, whose origins stem from Jean Piaget, and social constructivism, whose origins stem from Lev Vygotsky.

Vygotsky and Piaget are developmental dialecticists, as they both “offer examples of a dialectical approach in which development is part of the inevitable change taking place within real, holistic, contextualised and self-moving systems” (Bidell and Rogoff, 1988, p. 338). In spite of both being developmental dialecticists, Vygotsky and Piaget present different views of the constructivist theory. For Vygotsky (1962), knowledge is directly connected to speech, and verbal thinking commands learning and behaviour. Vygotsky’s work is the basis for social constructivism. Social constructivism asserts that knowledge is formed by cultural influences and progresses through cumulative involvement in different communities of practice (Scribner, 1985). For Piaget and Inhelder (1969), knowledge comes from actions, and logical thinking commands behaviour and mental representations, such as speech. Piaget is the father of cognitive constructivism. Cognitive constructivism argues that students actively reorganise knowledge in individual ways, building mental structures on current knowledge, educational experiences, and a multitude of other factors that facilitate understanding (Windschitl, 2002). Cognitive constructivism states that meaningful learning is based on personal experience (Brown et al., 1989). Both views of constructivism are important to science education. Nevertheless it is central to acknowledge the differences between them. If not, it creates confusion instead of promoting constructivist learning (Windschitl, 2002).

Rogoff (1990) compares Vygotsky’s and Piaget’s theories. First, Rogoff (1990) sustains that Piaget focuses on the individual, whilst Vygotsky focuses on the social basis of the mind. Second, Rogoff (1990) contends that both theories stress the importance of intersubjectivity, in social interaction. Nonetheless, there are differences in where intersubjectivity lies. In Piaget’s theory, social interaction is cooperation between individuals who work with independence and equality in each other’s ideas. In Vygotsky’s view, social interaction nurtures development through the direction provided by collaboration with people who are at higher level in the use of intellectual tools. Moreover, Piaget and Vygotsky seem to be opposed, in terms of the relation between individual and social in development (Rogoff, 1990). Vygotsky believes it goes from social to the individual while Piaget, sustains that development goes from the individual to the social. Finally, Piaget emphasized the importance of peer interaction. For Vygotsky, ideal partners are not equal. Interaction with more competent individuals fosters cognitive development.

This study is grounded in cognitive and social constructivism. Three arguments explain why cognitive constructivism is relevant to this study. Firstly, an action-oriented theory suits science outreach. Outreach objectives and practices aim to facilitate students experimenting and constructing their own learning through inquiry activities. This directs us to cognitive constructivism.
Secondly, there is a long tradition of using Piagetian ideas about development and learning in science education policies. The US Science Curriculum Improvement Study (Karplus, 1964) the Nuffield Science Project in the UK (Bliss, 1995), the Cognitive Acceleration through Science Education (CASE) from Kings College London (Adey and Shayer, 2008) and the OECD report on the Learning Sciences (Sawyer, 2008) are examples of this. Also the primary level of the Irish curriculum assumes a cognitive constructivist stance, as discussed in Chapter two. The Irish primary level curriculum (DES, 1999, p. 9) emphasizes “beginning from children’s ideas and practical experiences and reflecting on where children are in the progression towards the development of more scientific ideas”. The field of Learning Sciences and its connection to cognitive constructivism provides us with the third argument. Learning Sciences is a recent interdisciplinary field that is still in the process of defining itself (Sawyer, 2008). Learning scientists study learning in a variety of settings, including informal learning settings, where science outreach stands. Learning sciences’ research suggests several alternative models of learning. Specifically, they argue in favour of models that develop deep links between formal and informal schooling. They believe that collaborations between students and working professionals, such as scientists, are of key importance (Sawyer, 2008). Therefore, learning sciences argue for a greater connection between science education and science outreach. Research in the learning sciences field draws heavily on psychological studies of cognitive development. The learning sciences field considers Piaget’s constructivism absolutely critical to education (e.g. Dunbar and Klahr, 1989 in (Sawyer, 2008)).

The fact that science outreach aims to provide the students with the chance to experiment and construct their own learning, together with the support cognitive constructivism has gained from science education literature and policy documents, justifies why cognitive constructivism is the greater contributor to this research. Nonetheless, social constructivism also plays a relevant role in science education. Therefore, cultural interactions in learning environments are analysed in the methodological section of this thesis, through a survey instrument, as discussed in Chapters six and seven.

After analysing the relevance of constructivism in educational reform, and the role of cognitive and social constructivism in this research, the next section, examines the fundamentals of dialectics which concern Piaget and other constructive dialecticians. They constitute the basis of the dialectic criteria for evaluating teaching models presented in Chapter four.

### 3.2 Dialectic applied to science education

As described in Chapter one, the comparison carried out in this study uses a dialectic method to engage in a deeper discussion of science education and outreach. To do so, it is first important to understand the philosophical basis and main authors of dialectics. This is outlined in the following section.

#### 3.2.1. From Greek academy to developmental psychology

The use of Dialectic is traced back to the Greek world (Gadamer, 1976). According to Aristotle’s Sophist (cited in Spranzi, 2011) it originated from the work of Zeno of Elea. However, the first philosopher to use the word dialectic was Plato. For Plato (cited in Spranzi, 2011), dialectics were a practice to attain a higher kind of knowledge. Kant stated that the natural state of human thought incorporates dialectics, “as reason necessarily involves itself in contradictions” (Gadamer, 1976, p.5).
The value of dialectics as a process of thinking towards valid knowledge evolved after a controversy opposing Marx (2012) and Hegel (Gadamer, 1976). Marx was an advocate of outer-dialectics, in which the material world determines individual thought. Hegel, on the other hand, conceived inner-dialectics, a thinking process for allowing the thinker to attain concrete reality. The essence of this discussion is represented in the following quote:

My dialectic method is not only different from the Hegelian, but is its direct opposite. To Hegel, the life-process of the human brain, i.e. the process of thinking, which, under the name of ‘the Idea’, he even transforms into an independent subject, is the demiurges of the real world, and the real world is only the external, phenomenal form of ‘the Idea’. With me, on the contrary, the ideal is nothing else than the material world reflected by the human mind, and translated into forms of thought (Marx, 2012, p.25).

Dialectics are useful in the educational sciences because it is a philosophical discipline which targets the acquisition of knowledge (Hegel, 1995). Bidell and Rogoff (1988, p. 332) states that the dialectical approach to science “is an attempt to understand reality in all its complexity but especially in the fullness of its interrelationships and the contradictions it embodies”. In the classic Greek academies, most philosophers were teachers. They used dialectics for teaching, and for leading their students to knowledge in a progressive way (Nóbrega, 2005). Similar objectives guide education nowadays, as the Irish primary curriculum exemplifies: “children’s learning in science (…) involves children developing and constructing more scientific understanding” (DES, 1999, p.3).

The dialectical methodologies vary according to the convictions of their authors, such as Plato, Hegel, Marx or Piaget. Nonetheless, they all include a movement of opposition or of contradiction of the established knowledge to lead to a new knowledge. For Plato, the first author to use the word dialectic, dialectics was formed by two moments. First, it consists of relying on a hypothesis to ascend to a higher level of knowledge and second, descend towards conclusions by successive contradictions (Spranzi, 2011)

The notion of the movement of opposition and contradiction has evolved over the years. In Hegel’s inner dialectics, the contradiction is the necessary condition of any kind of progress. For Marx, the contradiction is the motor of class conscience or classes’ struggle (Marx, 2012). The passage from one level of knowledge to another may be envisioned in a continuous way or a discontinuous one. Hegel is representative of a continuous progression (Fine, 2001) while Marx and Piaget are representatives of a discontinuous progression. Figures 3.1 and 3.2 represent how these authors envision dialectics. On the right side of the following figures are the elements of the passage or the stages. On the left side, the dialectic tools of progression. In these, a result state (concrete/thesis, revolutionary status, equilibrium) becomes in time an established one, susceptible to be challenged (abstract/synthesis, post-revolutionary status, conservation).
Figure 3.1 represents the stages in Hegel’s dialectics. Progression for Hegel is overcoming (Aufhebung) the abstractness of things by means of a negation for reaching the concreteness of reality (Nóbrega, 2005). This movement concerns the individual and her/his thinking, and is directed to absolute self-determination. But Hegel was also a pedagogue of the reforms of Protestantism and of the constitutional monarchies, and eventually extrapolated the inner process to the social and political gains of his epoch (Nóbrega, 2005). The developmental psychologist Lev Vygotsky follows the Hegelian triad. Vygotsky (1986) states that the abstract concepts taught in school descend gradually to a stage of experience and become concrete. In this dialectic, there is a middle term. In this middle term, the non-spontaneous operations and the spontaneous operations meet each other.
Figure 3.2, below, represents the stages in Marx dialectics. For Marx, the movement is not ideal, as in Hegel’s, but real, not metaphysical but material (Joyce-Moniz, 1993). The movement is achieved in terms of a sequence of developmental stages concerning the organization of societies (Marx, 2012). Not, as indicated in Hegels’ model, through a continuous process of contradictions and ruptures.

As previously mentioned, Piaget (1959) is both the main pioneer of cognitive constructivism and an influential figure in dialectics. Piaget’s constructivism is dialectical. But his dialecticism is different from the other main theorists. For Piaget, knowledge does not come only from the outside or inner dialectics. Knowledge comes from both, since one implies the other, as seen in figure 3.3 below. There is a process of assimilation by the inside, in terms of what comes from the outside. Assimilation is only possible if the inside is ready to integrate what comes from the outside, through a process of accommodation. Piaget defines this process as equilibrium:

... equilibrium is ... an intrinsic and constitutive property of organic and mental life.... the theory of (human) development necessarily appeals to the notion of equilibrium, since all conduct tends to secure an equilibrium between internal and external factors ...

(Piaget, 1959, p.51).
The concept of equilibrium reflects a provisional balance between both movements of internalization and externalization. Those are not transcendental, nor the product of images or words. The dialectic of Piaget concerns actions and transformation of actions throughout psychological development, as the following quote explains:

It remains for us to speak of the status of contradiction in a dialectic founded on the implication between actions or operations. The big difference between these actions or operations and statements is that statements consist of "what is said," while actions (including the case where statements are subordinated to operations which integrate them into operatory structures) are characterized by "what is done," which are prior to language (at the sensory-motor level), prior to the constitution of the first statements, and are afterwards in competition with those statements.... (Piaget, 1980, p. 225/226).

Internalization refers to the progressive construction of logic structures, which indeed corresponds to the operations of traditional logics. The operations include identification, differentiation, coordination, ordering, classification, inclusion, implication and proposition. Externalization is the application of these operations to the physical world, for constructing its causalities, regulations and laws. Piaget generically calls them conservations (Piaget, 1959).

Nevertheless, Piaget’s dialectical theory remains in the Hegelian tradition of a dialectic triad, and somehow in the Marxist dialectics of discontinuous evolution (Joyce-Moniz, 1993). It follows these traditions in spite of Piaget not emphasizing the concept of contradiction or negation:

On the whole there are three dialectical movements to consider: (a) putting in interdependence those forms necessary for assimilation; (b) putting into interdependence the properties attributed to the object; and (c) synthesis of these forms and of these contents, which thus acquire the form of models..." (Piaget, 1980, p. 214).
The main dialectical method introduced by Piaget and Inhelder (1969) to help a child to experiment and think, is conceptual change (Villani, 1992). Conceptual change is a derivation of the pedagogical models of the Socratic and Plato’s model (Joyce-Moniz, 1993). In the latter, Plato uses an ascendant movement towards a principle, which represents the truth, and a descent movement from that principle to its consequences. This is carried out in order to conduct Meno through the dialectic process of: (a) making a statement, (b) doubting of its validity, and (c) making the correct statement (Hegel, 1995). In the former, Piaget introduces the problem to be solved (or the material to be manipulated) to the child, and (a) asks for an opinion, a measure, an estimate, etc.; (b) suggests a contradictory opinion to test the child’s confidence in his/her own opinion, and (c) asks the child to maintain or to reconsider his/her initial opinion (Villani, 1992). But what Piaget does here, most teachers who use a methodology of discussion also do (Joyce-Moniz, 1993). And Plato uses the dialectic method that characterizes the human exchange of ideas and the transformation of one’s ideas by the other. It is also a common procedure for the scientist to test her/his hypotheses and findings (Hyman, 1970).

To summarise, this section introduced the concept of dialectics, presenting the work from various classic and modern dialectical models and explaining why dialectics are important to science education. The dialectic methodologies of Marx, Hegel and Piaget were examined and compared. From this examination it was concluded that dialectics is a discipline that aims to understand reality in its interrelationships and contradictions. In dialectics, to achieve this understanding, there is a need for movement of opposition or contradiction that leads to new knowledge. Piaget’s epistemology has been applied extensively to science education (Steffe and Gale, 1995). Therefore, the next section analyses a specific model developed for science education based on Piaget’s epistemology.

3.3. Constructionism: a Piagetian-based model for science education

Piaget’s constructivism is core to understanding learning by children, and therefore for the learning of science (Sawyer, 2008). Nevertheless, Piaget did not specifically develop a method for the learning of science, formal or informal. His focus was on what children are interested in, and are able to achieve, at different stages of their development. The importance of Piaget’s theory is summarized in the following quote from the OECD report:

Before Jean Piaget, most people held to the common-sense belief that children have less knowledge than adults. Piaget argued a radically different theory: although children certainly possess less knowledge than adults, what’s even more important to learning is that children’s minds contain different knowledge structures than are in adults’ minds. In other words, children differ not only in the quantity of knowledge they possess; their knowledge is qualitatively different (Sawyer, 2008, p.8)

Piaget’s theory describes the evolution of a child’s way to think and do. It also describes the circumstances in which children are more likely to change (or not) their currently held views (Ackermann, 2001).

Followers of Piaget developed educational theories for learning in the science field. Simon Papert is one of these authors. Papert based his work on two of the implications of Piaget’s theory of learning:
• Teaching is always indirect. Students always reinterpret what it is being said to them according to their experience and knowledge. They transform the information they receive according to their mental structures;
• The transmission model of human communication doesn’t work to foster meaningful learning. Knowledge is not information to be delivered and afterwards memorized and applied by the receiver end. Knowledge is an experience that is acquired through interaction with the world, people and things (Ackermann, 2001).

These two implications are also important for science outreach. Chapter two illustrated that the majority of science outreach projects are founded on students experimenting with science through inquiry activities. This is aligned with the belief that knowledge is experience acquired through interaction. Acknowledging that teaching is indirect and that everything is reinterpreted by students is also a strong argument for outreach. This is because it supports the call for a more autonomous learning experience (Crane, 1994; Stocklmayer et al., 2010).

Simon Papert collaborated with Piaget and his work builds on Piaget’s theory of constructivism. He developed the theory of constructionism. In spite of emanating from Piaget’s research, Papert’s work reveals three new insights that make it pertinent for science education and outreach (Ackermann, 2001). Papert (1993) argued that constructionism:

shares constructivism’s connotation of learning as building "knowledge structures”(sic) irrespective of the circumstances of the learning. It then adds the idea that this happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity (p. 1).

The above quote reveals the first two new insights of constructionism. The first is related to the importance of constructing entities to obtain meaningful learning. The essence of Papert’s argument is that the use and building of public entities is core to constructing knowledge. Constructionism is focused on the idea that learning is most effective when it is part of an activity that the learner experiences. This activity involves constructing a meaningful product. The second insight relates to the contextualised nature of learning. For Papert, different individuals develop different ways of thinking in different contexts. Constructionism highlights a situated approach to learning that values the concrete, the local and the personal (Ackermann, 2001, p. 6). The last insight refers to concrete knowledge. Papert (1993) argues that traditional epistemologies inappropriate devalue concrete knowledge:

Traditional epistemology gives a privileged position to knowledge that is abstract, impersonal, and detached from the knower, and treats other forms of knowledge as inferior. But feminist scholars have argued that many women (and/or scientists) prefer working with more personal, less detached knowledge and do so very successfully. If this is true, they should prefer the more concrete forms of knowledge favoured by constructionism to the propositional forms of knowledge favoured by Instructionism (p. 10).

Papert presents a perspective of science learning that builds on Piaget’s work yet through a post-structural lens (Cronjé, 2009). Papert directs us to the “fragility, contextuality, and flexibility of knowledge under construction” (Ackermann, 2001, p. 8).
Papert’s three insights are relevant for science learning and science outreach. The first insight is the importance of building public entities. In science outreach, the idea of building public entities is an integral component of many projects. This is especially the case in computer science and engineering outreach, as detailed in Chapter two. A popular example is where students work with programmable toys and virtual objects, making them designers of games and simulations rather than mere users of such products (Sawyer, 2008). Furthermore, the Irish curriculum at primary level also has a specific section for constructionism, within its ‘design and make’ strand, which will be discussed in Chapter five. This strand “involves children in making the artefact they design and plan” (DES, 1999, p. 21). Papert’s constructionism offers an epistemological basis for the importance of constructing objects and therefore, of a strand such as ‘design and make’.

Furthermore, constructionism argues for a more contextualised and concrete learning of science, in contrast to the more traditional canonical science education, predominantly present in schools (Sawyer, 2008; Papert, 1993). This provides a strong argument for the necessity of including science outreach initiatives in schools, as concrete experimentation is core to the popular hands on/inquiry component of science outreach (Jeffers et al., 2004).

In summary, constructionism is a model of science learning based on Piaget’s epistemology that brings value to science education and outreach: the importance of constructing public entities, the contextualised nature of knowledge and the value of concrete knowledge. The next section presents the dialectic dichotomies that can be used for the explicit comparison of education models.

3.4. Dialectic dichotomies for science teaching and constructive learning

The term constructivism is applied to different ideological approaches and models (Steffe and Gale, 1995). This is the reason why, in this study, the theoretical foundations lay on a constructivist model that is dialectic in nature, as the dialectical method attempts to understand reality in its interrelationships and contradictions (Bidell and Rogoff, 1988). This constructivism is represented by dialectic developmental psychologists such as Piaget and Vygotsky (Bidell and Rogoff, 1988).

The underlying principle of constructivist learning is the acquisition of knowledge by the learner through an intentional and structured process of constructing significations in reality (Bruner, 1960, 1966; Furth, 1969; Piaget and Inhelder, 1969; Suchman, 1960). Therefore, the main objective of teaching is to present conditions that allow the learner to explore different processes for construing knowledge (Steffe and Gale, 1995). The construction is not a reproduction of previously learned significations. It is an active and continuous transformation of established knowledge into new knowledge. This objective can be attained through different methods and concepts (Joyce-Moniz, 1993). These methods and concepts can be represented as oppositions or dichotomies.

In an effort to address the overall aim of this study, which is to examine and compare primary teachers’ and science outreach practitioners’ understanding and perception of constructivist science teaching pedagogy, in order to improve the hybrid practice of science education/outreach in Ireland, four conceptual dichotomies were drawn from the literature in order to develop a dilemma methodology to encourage reflection on constructivist theory and practice. The four conceptual dichotomies are detailed below. These were chosen from the literature as they are the most relevant at science at primary level. As revealed below, albeit they are all related to primary science education, only the first three are brought for development within the methodology of this study,
as these three dichotomies relate well to both primary level teachers and science outreach practitioners.

**Autonomy/Dependency**

The first conceptual dialectic dichotomy relevant to this study is Autonomy/Dependency. Chapter two demonstrated that current education reforms value the autonomy of the student through inquiry learning and creativity. In constructivism, promoting the exploration and creativity of the student, implies promoting hers/his epistemological autonomy (Dutton, 1966). This is not the relativistic extreme of allowing a student to learn what they want when they desire. It is an epistemological aim for the school to encourage students’ free thinking, and construction of knowledge. The student is then, the main judge of the relevance of studied concepts and learning processes. As stated by Windschitl (2002 p. 164), “constructivism champions intellectual autonomy". Therefore, teaching should progressively evolve from learning conditions of dependency on the teacher to conditions favouring the epistemological autonomy of the student (Joyce-Moniz, 1993). Progressive is a key word here, as autonomy is a constructed path. The constructed path acknowledges the need of scaffolding by the teacher. If total autonomy is given to the student, without any scaffolding, a great harm is being done to inquiry learning (Blanchard 2010, p.273). McRobbie and Tobin (1997, p. 199) define what autonomy means in a constructivist stance:

Students should have control over their own learning and construct meanings for their experiences in terms of what they know at the time of learning. Students need time to reconstruct their extant knowledge and to use it to make sense of experience and, as necessary, to reconstruct their understandings.

The dialectical opposite of autonomy is dependency, where the teacher controls every aspect of the learning process. It is represented by an objectivist type of teaching (Kim and Tan, 2011; Windschitl, 2002). In the objectivist or traditional model of teaching, lecturing and demonstration are the favoured modes of teaching. This model argues that language can be used as a precise tool to describe and transfer the reality to students. According to Davis (2003), students have restricted autonomy because teachers are obliged to teach a set curriculum to all students. Thus, they have to take care that specialization remains within a certain boundary.

**Induction/Deduction and Conceptual Change**

The second conceptual dichotomy relevant to this study is Induction/Deduction which is related to the constructivist method of conceptual change. Dialectics in learning may follow similar structured patterns of dialectics in the world. On one side, there are processes of opposition, contradiction, revolution or deconstruction of established significations, previous knowledge, or systems of action. On the other, processes of integration, stability or reconstruction of new significations and actions (David, 1982). In developmental terms, operations of deconstruction may imply movements of inquiring, differentiating, de-centering or contradicting. Operations of reconstruction and integration use movements of including, ordering, classifying, compensating or synthesizing (Joyce-Moniz, 1988). Most learning conditions aim to elicit the student to engage in the operations of deconstruction. The teacher introduces a stimulus, concept, problem or a thematic
question, which provokes the student’s epistemological conflict (e.g., Ausubel, 1963; Suchman, 1960). This conflict is of epistemological nature, since it elicits the ‘curiosity for knowledge’ (Joyce-Moniz, 1988). That is, until the conflict is solved by a new signification, the student maintains her/his motivation for dialectic inquiring.

The conceptual change method of Piaget and Inhelder (1969), with widespread use in science education, is an example of the dialectic inquiry. It is a dialectical method that unifies the dichotomy Induction/Deduction in science education. In the inductive phase, the educator creates the conceptual conditions for enabling the student to experiment in a concrete reality. In the deductive phase, the educator asks the student for a deductive explanation of previously formulated hypotheses or conclusions. In both strategies, but with more emphasis on the latter, the teacher dialectically confronts the student with opposing views, contradicting inferences. The teacher does this to test the student’s assertions and her/his resistance to alternative views. In conceptual change we have deconstruction/reconstruction and Induction/Deduction.

The dichotomy Induction/Deduction is discussed extensively in the science education literature. It is usually discussed in relation to what to teach. One view argues that science education should be focused on the processes of science through an inductive methodology. According to this inductive view, the student reaches the product through the process (Stocklmayer et al., 2010). As stated by Reid (2011, p.51):

> The process of inductive reasoning stimulates students’ thinking as they examine specific facts, data, or visual information and form a generalized idea about their observations. This kind of reasoning moves from specific information to a generalization, or summary.

The opposing view believes that the focus of science teaching should be on the products of science through a deductive methodology (Kirschner et al., 2006). Kirschner et al. (2006, p. 75) explains the deductive methodology:

> Novice learners should be provided with direct instructional guidance on the concepts and procedures required by a particular discipline and should not be left to discover those procedures by themselves […] Direct instructional guidance is defined as providing information that fully explains the concepts and procedures that students are required to learn.

The inductive path is a down-up one (e.g., from concrete facts to general significations) and the deductive path is an up-down one (e.g., from concepts to their attributes). Although the inductive view is normally the one associated with a constructivist methodology (Kirschner et al., 2006), this is erroneous as both inductive and deductive thinking are present in the construction of knowledge (Joyce-Moniz, 1988; Windschitl, 2002). The problem reported by the science education literature is that the focus of science teaching is mainly the products of science (Aikenhead, 2006).

**Creativity/ Guidance: From Student led to teacher led construction**

The third constructivist dichotomy relevant to this study is construction by self/ co-construction. Learning is constructing, since the student is systematically elicited to carry on inner and outer dialectics (Piaget, 1959). And the teacher does exactly the same. Teacher’s significations
of learning influence and transform student’s significations and consequent actions. At the same time the teacher is also modelled and transformed by the interaction with the students. The dialectics of teaching and learning is what Piaget (1959) calls co-operation, Freire (1970), co-investigation and more recently constructivists call co-construction (Palincsar, 1998).

Co-construction may evolve through authoritarian school practices, leading to students’ epistemological and attitude dependency. Alternatively they can evolve through democratic practices, enfolding student’s self-construction. In constructivism, the aimed direction is of increasingly epistemological (knowledge) and operational (practice) openness. Operational and epistemological openness are a requisite to promote creativity. The constructivist philosophy of learning stresses the role of knowledge creation in opposition to transmission of knowledge. This automatically directs us towards creativity. To be creative, students need to construct meaning, explanations, hypothesis and procedures new to them (Givens, 1962). The creation and implementation of ideas is one of the main objectives of studies on creativity (Newton and Newton, 2010). Beghetto (2007, p.1) explains how creativity should be promoted in the science classroom:

Creativity involves the ability to offer new perspectives, generate novel and meaningful ideas, raise new questions, and come up with solutions to ill-defined problems. Classroom discussions provide an ideal forum for students to develop their creative thinking skills. Indeed, teachers can support students’ creative thinking by encouraging and rewarding students’ novel ideas, unique perspectives, and creative connections.

Moreover, divergent thinking is a key component of creativity in the classroom. Without divergent thinking, students cannot develop unique ideas, limiting creativity. As Beghetto (2007, p.175) argued: “the habitual dismissal of unique ideas spells trouble for the cultivation of creative thinking”. This dismissal is visible by the need to give guidance to students as described in McRobbie and Tobin (1997, p. 200):

I want students to take a particular approach to solving problems, and I want it to be a fairly structured approach. In the solution of chemistry problems I want them to follow a set procedure, so I'm trying to build them a model of problem solving that I think will guarantee them success.

This view is supported in Kennedy (2005) where it is stated that creative thought, particularly in subjects like science, is considered secondary to the acquisition of established procedures and is a distraction from the purpose of the lesson. These views that argue for more guidance endanger the promotion of unique ideas. To develop unique ideas the path followed by the teacher must be towards student led construction (Sternberg and Grigorenko, 2004). From a Piagetian perspective, this interaction of epistemologies should be balanced. Open (student led) construction is the dialectical opposite of guided (teacher led) co-construction.

Simplicity/Complexity and the importance of Concrete/Abstract knowledge

The last dichotomy is Simplicity/Complexity, in which concrete/abstract knowledge is relevant. Developmental dialecticists such as Piaget, Bruner or Kohlberg (1966) assert that teaching must be adapted to the level of dialectic actions of the student. In terms of concrete knowledge, the
student may use concrete means for differentiating, ordering or classifying the learning material or conditions. In terms of abstract knowledge, the student may use a formal means for inferring, implicating or rationalising those conditions. At the different types of knowledge, both concrete and abstract, the student uses different dialectic operations. The teacher must balance concrete/abstract knowledge with the level at which the students are. If not, the teaching can lead to a lack of understanding and, as such, poor learning. The co-construction of knowledge is only possible if both teacher and student communicate at the same level, using similar dialectic means. The distinction between concreteness and abstractness is a pre-requisite of models that advocate developmental views for their teaching strategies (Wadsworth, 1978).

Teaching at a level consistent with student ability directs us to Simplicity/Complexity. Concepts and processes developed in the school form a hierarchy that is increasingly open, complex and abstract (Schecker and Parchmann, 2007; Weinert, 2001). Constructivist literature argues that teaching objectives should follow the natural psychological development from simplicity towards complexity (Wadsworth, 1978). As Marx and Piaget have suggested, the dialectic development, should be represented with a tri-dimensional spiral of knowledge. In this spiral, each curve is larger than the previous one. This has led to the concept of spiral curriculum (Bruner, 1960). The concept of the spiral curriculum is evident in the Irish primary level curriculum (DES, 1999). In the spiral curriculum, the early teaching of any subject should emphasise grasping basic ideas intuitively. After that, the curriculum revisits these basic ideas, repeatedly building upon them until the pupil understands them fully. The progression is not a question of timing. Different learners may take different amounts of time to accede to similar levels. The previous knowledge is deconstructed and transformed for generating the following knowledge. This conception also emanates from the Hegelian tradition. First, there is an antithesis opposed to a thesis. The conflict is solved at a higher level of abstraction that synthesizes the previous terms of the problem (Nóbrega, 2005).

In summary, a constructivist developmental view of teaching emphasizes a staged approach, which focuses on the progressive developmental level of the children.

The use of dialectic dichotomies for comparison purposes

The constructivist view of teaching promotes the student’s epistemological autonomy and progress towards complexity (Wadsworth, 1978; Windschitl, 2002). This view of knowledge creation advocates creativity. To achieve these objectives inductive/deductive processes and concrete/abstract knowledge are present. In order to achieve student progress, it is essential that the teacher is aware of the next level that the students should be challenged towards.

This constructive dialectics may be represented, for comparison purposes, in terms of epistemological and operational dichotomies. The conceptual dichotomies are Autonomy/Dependency, Induction/Deduction, Creativity/Guidance and Simplicity/Complexity. Most importantly, the dichotomies fall into a continuum. This allows the observer to situate their relative position on the continuum between both concepts (Joyce-Moniz and Barros, 2005). The observer can then identify and discuss their implementation of teaching objectives and methodologies. This is not in Manichean terms of one or another, but in terms of their relative proximity to those extremes. That is to say, educational models should be flexible to locate, on a continuum, purposes and practices in relation to their conceptual opponents (Joyce-Moniz, 1993; Joyce-Moniz and Barros, 2005).
The conceptions of dialectical constructivism (David, 1982) are used in this study in two ways. Firstly, they are used to analyse models of teaching in Chapter four. Secondly, the conceptual dichotomies support the dilemmatic situations that are presented in the methodological section of the study. For methodological purposes the conceptual dichotomies that are going to make up the conceptual dilemmas and guide the pedagogical ones are Autonomy/Dependency, Induction/Deduction, Creativity/Guidance. Simplicity/Complexity is not developed methodologically since 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 regularly. Therefore, science outreach officers do not follow up the development of students as closely as primary level teachers do. The specific method used to present the conceptual dilemmas consists of the explicit presentation of perspectives from each of the opposing concepts based on claims from the education literature analysed in this Chapter. The conceptual dichotomies and claims are presented in figure 3.4

Figure 3.4 Conceptual dichotomies used in this study

<table>
<thead>
<tr>
<th>Conceptual Dichotomies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Autonomy</strong></td>
</tr>
<tr>
<td>Students should have control over their own learning and construct meanings for their experiences in terms of what they know at the time of learning. Students need time to reconstruct their extant knowledge and to use it to make sense of experience and, as necessary, to reconstruct their understandings. (McRobbie and Tobin, 1997)</td>
</tr>
<tr>
<td><strong>Dependency</strong></td>
</tr>
<tr>
<td>Teachers are obliged to teach a certain curriculum to all students. Thus, they have to take care that specialization remains within a certain boundary. All students should at least have a superficial understanding of all scientific aspects of a project, which in turn restricts the autonomy of students to specialize into areas of their interest and neglect areas of less interest (Davis, 2003)</td>
</tr>
<tr>
<td><strong>Induction</strong></td>
</tr>
<tr>
<td>Providing opportunities for inductive thinking is one way to guide students towards formal inquiry. The process of inductive reasoning stimulates students’ thinking as they examine specific facts, data, or visual information and form a generalized idea about their observations. This kind of reasoning moves from specific information to a generalization, or summary. An inductive lesson allows students to examine data, search for critical attributes, and thus develop complex learning skills (Reid, 2011).</td>
</tr>
<tr>
<td><strong>Deduction</strong></td>
</tr>
<tr>
<td>Novice learners should be provided with direct instructional guidance on the concepts and procedures required by a particular discipline and should not be left to discover those procedures by themselves. Direct instructional guidance is defined as providing information that fully explains the concepts and procedures that students are required to learn (Kirschner et al., 2006)</td>
</tr>
<tr>
<td><strong>Creativity</strong></td>
</tr>
<tr>
<td>Creativity involves the ability to offer new perspectives, generate novel and meaningful ideas, raise new questions, and come up with solutions to ill-defined problems. Classroom discussions provide an ideal forum for students to develop their creative thinking skills. Indeed, teachers can support students’ creative thinking by encouraging and rewarding students’ novel ideas, unique perspectives, and creative connections. (Beghetto, 2007)</td>
</tr>
<tr>
<td><strong>Guidance</strong></td>
</tr>
<tr>
<td>Creative thought (Kennedy, 2005), particularly in subjects like science mathematics is secondary to the acquisition of established procedures and is a distraction from the purpose of the lesson (Beghetto, 2007). I want students to take a particular approach to solving problems, and I want it to be a fairly structured approach. In the solution of problems I want them to follow a set procedure, so I’m trying to build them a model of problem solving that I think will guarantee them success. (McRobbie and Tobin, 1997)</td>
</tr>
</tbody>
</table>

In Chapter five the specific conceptual and pedagogical dilemmas based on the conceptual dichotomies are explained and presented. The next Chapter examines the dichotomies in the context of relevant models of science education. The analysis of these models will support the pedagogical dichotomies presented in Chapter five.
Chapter Four: Models of teaching and learning in science education and science outreach
4.1 Introduction

This Chapter presents four models of learning relevant in science education and analyses them through the conceptual dichotomies presented in Chapter three. This will allow the development of the conceptual and pedagogical dilemmas that will be used in the interview methodology. Chapter two concluded that science outreach needs to develop a stronger relationship with science education. It demonstrated that science outreach practices, for the most part, involve inquiry learning rooted in constructivist epistemology. Nonetheless, science education methods are not limited to inquiry learning. Other methods are relevant and different practices of science outreach can take advantage of them. Consequently, this Chapter presents a variety of science learning methods and analyses them through a constructivist lens. The constructivist lens is used because, as concluded in Chapter two, reform in science education and outreach is grounded on the principles of constructivism. This analysis uses the dialectic and constructive dichotomies presented in Chapter three.

The first section of the Chapter presents pedagogical models used in science education. It introduces the models, the phases of each model and their current application. The second section examines the most popular model in current science education: inquiry learning. The third section of the Chapter analyses the models according to the dialectic dichotomies presented in Chapter three. The dichotomies are used because they allow comparison of the models according to constructivism.

4.2 Models of teaching and learning

This section presents four models of teaching and learning that have widespread use in science education. This presentation draws from Bruce Joyce and Marsha Weil’s (1972 1st edition, 2000 6th edition) metamodel. Their work deals with the major psychological and philosophical approaches to teaching and schooling. They selected and revised 20 models of teaching and learning. Joyce and Weil’s (1972) work provides a direct link between educational foundations and student teaching. Their classification guides the choice of the models presented here. Joyce and Weil’s (1972) conclusions and synthesis of each model give content to the dialectic and constructive analysis of its main assertions and procedures.

The selection of the models was guided by a simple criterion: the models discussed have been applied in science education and reveal dialectic and constructive features. Furthermore, each of the models chosen aligns with the conceptual dichotomies argued as relevant in primary science within Chapter three. This will allow for the design of pedagogical dilemmas of the aforementioned dichotomies. The models selected are classified within the ‘information processing family’ (Joyce et al., 2000). This family was selected because information processing models “emphasize ways of enhancing the human being’s innate drive to make sense of the world by acquiring and organizing data, sensing problems and generating solutions to them” (Joyce and Weil, 2000, p.17). Therefore, these models reflect the teaching and learning methods argued by policy documents and science education reports in Chapter two. From the seven models described in Joyce and Weil’s metamodel, four are selected: Thinking Inductively, Advance Organisers, Inquiry Training and Biological Science Inquiry Model. The selection of these precise four models is now explained. Inquiry Training is selected because it represents an inductive process of analysing information and creating concepts. Chapter three explained the importance of the dichotomy inductive/deductive for science education. Therefore, the next model selected is Advance Organizers. Advance Organizers is a
deductive model that provides students with a cognitive structure for comprehending material presented through lectures (Joyce and Weil, 2000). The last two models selected are Inquiry Training and Biological Science Inquiry Model. These models are selected because they were both specifically designed for science education (Schwab, 1963; Suchman, 1960). Furthermore, these models originate from the most favoured model in science education policy documents: inquiry learning. The section starts with the presentation of Thinking Inductively.

4.2.1 Think Inductively, by Hilda Taba

One scarcely needs to emphasize the importance of critical thinking as a desirable ingredient in human beings in a democratic society. No matter which views people hold of the chief function of education, they at least agree that people need to learn to think in a society, in which changes come fast, individuals cannot depend on routinized behaviour or tradition in making decisions (…) In such a society there is a natural concern that individuals be capable of intelligent and independent thought. (Taba, H. in Costa and Loveall, 2002, p. 61)

The model of teaching developed by Hilda Taba comes from her work with John Dewey and Benjamin Bloom (Costa and Loveall, 2002). As the previous quote asserts, teaching to think is a core outcome of education.

Taba and Spalding (1962) introduces an approach to curriculum design that champions critical thinking. The concern is not to try to teach the largest amount of data possible. Instead, the main focus is on students developing concepts from objects, examples and information (Micotti, 1995). Students form the concept by analysing the information given and creating and testing hypotheses that describe the relationships among the data (Joyce and Weil, 2000). In line with this pedagogy, Taba stresses that knowledge has three stages: facts, basic ideas/principles and concepts. Taba believes that education is overly focused on the memorization of facts; she states that facts have to be carefully selected in order to support the next levels of knowledge, and as such form a fundamental stage in knowledge construction (Costa and Loveall, 2002). The Thinking Inductively model is based on three postulates about thinking that are represented in figure 4.1.

Figure 4.1 Hilda Taba three postulates about thinking

<table>
<thead>
<tr>
<th>Thinking processes</th>
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</thead>
<tbody>
<tr>
<td>(a) The teacher can guide the process of interiorization and concept formation. The teacher can stimulate the student to execute mental process and thus the student will need less direct support;</td>
</tr>
<tr>
<td>(b) Thinking is an active transaction between individual and data. So, teaching materials may enable cognitive activities</td>
</tr>
<tr>
<td>(c) The process of teaching to think has a specific sequence and teaching strategies must take this sequence into account</td>
</tr>
</tbody>
</table>

In the first postulate, Taba and Spalding’s (1962) reasoning is that the teacher’s role is to help the student develop an inductive thinking ability through practice (Joyce and Weil, 2000). In the second postulate, Taba asserts that students are presented with data from a domain, they organize it, making inferences to hypothesise and explain the concept. In the last postulate, Taba and Spalding’s (1962) argument is that students master thinking skills in a sequential way from simpler to more complex ones. From these three postulates, Taba developed a teaching model based on
three inductive teaching strategies: concept formation, interpretation of data and application of principles. The teaching strategies are explained further below.

4.2.1.1 Teaching Strategies

All of the strategies emphasize cooperative learning with active students (Taba and Spalding, 1962). The three strategies are initiated by the teacher. Therefore, the teacher assumes a controlling position (Joyce and Weil, 2000). Nevertheless, as students master the strategies they become more autonomous. The three strategies are now explained (Joyce and Weil, 2000).

**Concept formation**

In this teaching strategy, the teacher presents data that exemplifies the concepts being developed. This data can be objects, examples and information. The student starts by identifying and comparing the data relevant to a problem. The student then groups those items according to the basis of similarity and non-similarity. Ultimately the student develops categories and labels for the groups. By doing this, the student develops a concept that might be seen as correct or incorrect by the teacher. To the student, even if temporarily, the initial concept organizes her/his view of reality.

**Interpretation of data**

This phase consists of the process of developing interpretations, inferences and generalizations from the concrete examples given. Through teachers’ questions, the student is led to identify critical aspects of the data presented. Afterwards, the student explores relations between the data while the teacher asks questions concerning cause and effect, such as why did this happen. The student then goes beyond the given examples, by making inferences in relation to the observed reality. The student tries to find meaning to what she/he observed, drawing a hypothesis. Finally, the student derives conclusions based on conjectures and inferences about the data.

**Application of principles**

The last phase is the only deductive phase in Taba’s teaching model. Here, the student is asked to apply the newly developed concepts to explain new realities. It starts with a problem, or with a set of conditions that are unfamiliar. It concludes with the student formulating a hypothesis in respect to possible solutions or consequences.

4.2.1.2 Applications and influences

Taba’s work is recognized as having influenced educational thought throughout the world (Hunt, 2010). Her model has been used in a wide variety of curriculum areas with primary and second level students (Joyce and Weil, 2000).

When debating curriculum change and the emphasis on processes or facts, her work is considered a significant contribution to the field of education (Costa and Loveall, 2002). The following quote exemplifies her influence:

Taba’s scientific heritage in the field of educational philosophy, intergroup education, and curriculum development undeniably provided educational theory with many
important ideas of lasting value. Her work in the field of curriculum studies helped to challenge and reform understandings of the way schools help to prepare children to live in a multicultural democracy. (Hunt, 2010, p. 870)

The essence of Hunt’s (2010) argument is that Taba’s inductive methodology and emphasis on the thinking processes influenced all fields of teaching and curriculum development.

4.2.2 Learning from presentations: Advance Organizers by David Ausubel

Existing cognitive structure, that is an individual’s organization, stability, and clarity of knowledge in a particular subject matter field at any given time, is the principal factor influencing the learning and retention of meaningful new material (Ausubel, 1963, p. 217).

David Ausubel’s model of teaching emphasizes meaningful learning of students through the use of presentational methods of teaching, such as lectures (Joyce and Weil, 2000). Ausubel states that for meaningful learning of new material to occur, a central role must be given to Advance Organizers.

Advance Organizers are the tools that allow a connection between pre-existent knowledge and new knowledge (Ausubel, 1963). Ausubel defines them as a preliminary statement of concepts that are wide enough to encompass the new knowledge to be apprehended. They form a conceptual bridge between new and old knowledge (Woolfolk and McCune-Nicolich, 1986). Thus, Ausubel believes that the wider concept should be presented first. Afterwards, the teacher should draw upon more specific and concrete particularities, thus allowing a well-organized, clear and stable understanding of the initial concept presented (Ausubel, 1963). The use of Advance Organizers is rooted in Ausubel’s belief in the hierarchical organization of knowledge (Ausubel, 1963). Ausubel argues that this organization evolves from concrete to broad, abstract concepts (Joyce and Weil, 2000). Therefore, the teacher must present the advance organizer to provide the students with abstract anchors between different concepts.

Another central concept on Ausubel’s learning model is meaningful reception. The author argues that his model only applies to expository teaching, such as lectures and readings (Joyce and Weil, 2000). Ausubel believes that meaningful learning can be obtained from presentations. According to his theory, it is not inquiry or expository teaching that makes learning meaningful or rote, it is the way knowledge is treated. Therefore, contrary to an inductive approach, the Advance Organizers deliver concepts to students directly (Joyce and Weil, 2000).

The model of teaching and learning has three phases of activity that are now presented.

4.2.2.1 Phases of activity

Ausubel’s model of Advance Organizers has three phases. The first one is the presentation of the advance organizer, the second the presentation of the learning task or material, and the third is the strengthening of cognitive organization. Phase three assesses the connection of the learning material to existing ideas (Joyce and Weil, 2000). The teacher maintains control of the lesson during the three phases, as the new learning material needs to be related to the organizers and it is necessary to help the students distinguish new material from previously learned material (Joyce and Weil, 2000). Nevertheless, Ausubel (1963) states that in phase three the learning situation is more
interactive, with students initiating comments and questions (Ausubel, 1963). Phase one is now described.

**Phase 1 – Presentation of the advance organizer**

Phase one of the Advance Organizers model consists of three activities: explain the aims of the lesson, introduce the advance organizer and encourage awareness of relevant knowledge.

In the first step the teacher presents the aims of the lesson. The teacher does this in order to capture students’ attention and orient them towards the learning goals. The advance organizer is at a higher level of organization, this is what distinguishes it from an introductory overview. Therefore, it has to be explored intellectually. To present the organizer, the teacher has to: identify the defining attributes; give examples, provide context and repeat. In the end of the first phase, learners’ awareness of prior knowledge and experience relevant to the organizer needs to be activated. The students are then ready to be presented with the learning task.

**Phase 2 – Presentation of the learning task or material**

The second phase starts with the presentation of the learning material by the teacher. Ausubel emphasizes that the organization of the material needs to be made explicit. This way, students can understand the logical order of the material and how that structure connects to the advance organizer. Therefore, the structure of the learning material is set *a priori* by the teacher.

**Phase 3 – Strengthening cognitive organization**

In the last phase, the new material is “anchored” into the students’ cognitive structure (Ausubel, 1963). Ausubel identifies four activities necessary to promote this phase. These are represented in figure 4.2.

**Figure 4.2 Phase 3 of Ausubel’s model of Advance Organizers** (adapted from Joyce and Weil, 2000)

<table>
<thead>
<tr>
<th>Activities to strengthen cognitive organization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Promote integrative reconciliation: (1) Remind students of the ideas (the larger picture); (2) Ask for a summary of the major attributes of the new learning material; (3) Repeat precise definitions; (4) Ask for differences between aspects of the material; (5) Ask students to describe how the learning material supports the concept or proposition that is being used as a subsume</td>
</tr>
<tr>
<td>Promote active reception learning: (1) Asking students to describe how the new material relates to a single aspect of their existing knowledge; (2) Asking students for additional examples of the concept or propositions in the learning material; (3) Asking students to verbalize the essence of the material, using their own terminology and frame of reference; (4) Asking students to examine the material from alternative points of view; (5) Relating the material to contradictory material, experience, or knowledge</td>
</tr>
<tr>
<td>Electing a critical approach to the subject matter: Clarification</td>
</tr>
</tbody>
</table>

The different activities are illustrated in figure 4.2 above. The specific lesson and the specific topics should guide the teacher in choosing the specific techniques. This last phase, in contrast with the first two, should be initiated both by teachers and students, giving more control to the student (Joyce and Weil, 2000).
4.2.2. Applications and influences

The Advance Organizers learning model has been applied to all areas of science education with students of different ages (Joyce and Weil, 2000). The Advance Organizers model continues to be used in education and especially in science education. Westbroek et al. (2010) used it with positive initial results in a Chemistry curriculum. The authors adapted the theory of Advance Organizers by “using a science-related practice as a source for Advance Organizers that integrate motivational and cognitive functions” (p.600). The reasoning for incorporating Ausubel’s advance organizers into the curriculum is explained in the following quote:

In a professional practice, professionals more or less know how the activities they perform will contribute to the purpose they want to achieve. We expected that this structure of means-end relationships could be adapted to yield Advance Organizers for educational use (Westbroek et al., 2010 p. 604).

In other words, they used Ausubel’s theory to evoke in students, a clear understanding as to why they are learning. Westbroek et al.’s (2010) main objective was to use Advance Organizers as a teaching strategy to explicitly show students the connection between the method and the intended outcome.

4.2.3 Inquiry models: Inquiry Training, Biological Science Inquiry Model and Inquiry Learning

Inquiry learning is the most cited and debated pedagogy in science education (Blanchard et al., 2010). Inquiry learning models emphasize the processes of science rather than the memorization of science facts. This emphasis on process methods is traced back to the work of Dewey (1910) who argued that knowledge is a product of inquiry. The philosophical routes for the application of inquiry learning to science education emerged from the work of developmental constructivists as Piaget, Brunner or Vygotsky. The emphasis in inquiry was first translated into science education by two authors: J. Suchman (1960) and J. Schwab (1963). These authors were the first to develop models of learning for science education based on inquiry methods. These first models of inquiry for science education were based on the idea of students learning in a similar way to how scientists worked (Joyce and Weil, 2000). Since the work of Schwab and Suchman, inquiry learning has evolved and is now the model advocated by policy documents and within the science education literature, as discussed in Chapter two. The models of Suchman and Schwab are now described.

4.2.3.1 Inquiry Training by J. Suchman

Inquiry is the active pursuit of meaning involving thought processes that change experience to bits of knowledge (Suchman, 1960, p. 23).

Suchman was one of the first authors in education to propose an Inquiry Training model for science education (Joyce and Weil, 1974). For Suchman (1960) the general goal of the Inquiry Training model is to help the student develop the skills necessary to raise questions and search out answers. Suchman believes that these questions need to stem from their curiosity. The model is used to help students to learn how to ask questions and solve problems using inquiry. The inquiry is built around intellectual confrontations with the student being introduced to puzzling situation and inquiring about it. This confusing event, the problem, is selected to raise the interest of the students,
triggering the process of inquiry. In the Inquiry Training model the process of inquiry has five phases that are now analysed.

4.2.3.1.1 Phases of Inquiry Training

Inquiry Training starts with the confrontation of a problematic situation (Suchman, 1960). It continues with phases two and three where the process of data gathering occurs. In phase four, students organize the information obtained and try to come up with an explanation of the problem. Finally, in the last phase the students analyse the approaches they followed to solve the problem. The model is highly structured with the teacher controlling the progress through the different phases, although both participate as equals where relevant ideas are concerned (Joyce and Weil, 2000). The different phases are now described according to Suchman (1960) theorization.

Problem Confrontation

In the first phase students are faced with a puzzling problem, situation or event. This phase requires that the teacher presents both the situation and the inquiry procedures to the students (Joyce and Weil, 2000).

Data Gathering—Verification

In the second phase students gather information to verify the details of the discrepant event. Students ask the teacher questions that are answered by a ‘yes’ or ‘no’ in order to verify the facts. Suchman emphasizes the yes or no procedure because it requires the students to put several factors together and form hypothesis that the teacher either confirms or rejects (Joyce and Weil, 2000). If not, students could just ask the teacher to explain the phenomenon.

Data Gathering—Experimentation

Phase three starts when the students have identified the variables that are relevant to the event, creating hypothesis that are tested through experiments. In this phase, students turn their questions to the relationships among the variables of the problem, and then conduct experiments to test those relationships (Joyce and Weil, 2000).

Organization and Explanation

In phase four the teacher asks the students to organize the information they obtained and to work out an explanation to address the research problem. This phase is carried out in a group, where the different explanations are combined to form the one that fully addresses the problem.

Analysis

In the final phase, the teacher asks the students to analyse their pattern of inquiry and propose improvements to their process. This phase is essential to make the inquiry process a conscious one and for students to improve their inquiry capabilities (Joyce and Weil, 2000).

4.2.3.2 Biological Science Inquiry Model: Invitations to Inquiry by J. Schwab

If we examine a conventional High school text, we find that it consists mainly or wholly of a series of unqualified positive statements. (...). This kind of exposition (...) has serious objections to it. Both by omission and commission. It gives a false and misleading
picture of the nature of science. By commission (...) it gives the impression that science consists of unalterable, fixed truths. Yet, this is not the case. The sin of omission (...): it fails to show (...) that is a body of knowledge forged slowly and tentatively from raw materials BSCS 1966 in (Joyce and Weil, 1972, p.178).

Joseph Schwab is responsible for the emergence of inquiry learning as a core theme in curricular reform in the 1960’s (Bybee, 2010). Schwab (1963) established that science is tentative and always evolving. Nevertheless, teachers and curricula were portraying it as a rhetoric of conclusions, in which scientific knowledge seems unalterable and complete. Schwab (1963) believed students needed to be taught in a new form in order to become “fluid enquirers” (p. 173). He argued that in order to learn science, students themselves should ‘inquire’ as a learning technique. To achieve this, he felt that a tentative definition of the nature of science should be presented, a definition that emphasizes its ever changing and evolving nature.

Schwab (1963) applied his work and model of teaching to the Biological Sciences Curriculum Studies (BSCS) and as such, scientific inquiry is the guiding principle for the BSCS curriculum (Bybee et al., 2006). According to Schwab (1963) the curriculum was designed to “show students how knowledge arises from the interpretation of data (...) proceeds on the basis of concepts and assumptions change as our knowledge grows” (p.46). Each inquiry activity starts with an invitation to inquiry that describes a real-life scientific study. The sets of invitations are sequenced, becoming more and more complex, to lead the students to more sophisticated concepts (Joyce and Weil, 2000). The inquiry model contains four phases that are now presented.

4.2.3.2.1 Phases of the Biological Sciences Inquiry Model

The Biological Sciences Inquiry Model is followed throughout the invitations to inquiry presented in the Biological Science Curriculum (Schwab, 1963). In this model, a problem in relation to an investigation is described. This is followed by inducing students to create methods of inquiring that will overcome the problem in the investigation (Joyce and Weil, 2000). In this process, the teacher’s task is to emphasize the process of inquiry creating a cooperative environment. To achieve this result, the model follows four sequential phases.

Phase 1

In the initial phase, an area of investigation is proposed to the student, including the methodologies used in the investigation.

Phase 2

In the second stage, the problem is structured, so that the student identifies a difficulty in the investigation. The difficulty may be one of data interpretation, data generation, the control of experiments or making inferences.

Phase 3

In this phase the student is asked to speculate about the problem. This is carried out in order to identify the difficulty involved in the inquiry.

Phase 4
In the last phase the student is asked to speculate on ways of addressing the difficulty. This is achieved either by redesigning the experiment, organizing data in different ways, generating data or developing constructs.

4.2.3.3. Applications and influences of the inquiry models

The most recent forms of inquiry can be rooted to Suchman and Schwab’s works. There are numerous models that follow a structure of inquiry that is similar to the initial model developed by Suchman (Bell et al., 2010). Models differ mainly in relation to the degree of control given to the student in the inquiry activity. They also differ in terms of the number of steps the model has, and the names they are given.

Two inquiry learning models recently developed are the Schwarz and White’s (2005) Doing Science and the Cuevas et al. (2005) one. Table 4.3 shows the different steps both models have and compares them to Suchman’s model.

Figure 4.3. Three models of science inquiry

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>(a) Question,</td>
<td>(a) Questioning;</td>
<td>(a) Problem Confrontation</td>
</tr>
<tr>
<td>(b) Hypothesise</td>
<td>(b) Planning;</td>
<td>(b) Data Gathering—Verification</td>
</tr>
<tr>
<td>(c) Investigate</td>
<td>(c) Implementing;</td>
<td>(c) Data Gathering—Experimentation</td>
</tr>
<tr>
<td>(d) Analyze</td>
<td>(d) Concluding;</td>
<td>(d) Organization and Explanation</td>
</tr>
<tr>
<td>(e) Model</td>
<td>(e) Reporting.</td>
<td>(e) Analysis</td>
</tr>
<tr>
<td>(f) Evaluate</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Although differences exist between the models, the grounding in Suchmans’ work is undeniable. Schwab’s work is also very relevant to the inquiry learning model that now dominates science education literature and curricula (Bell et al., 2010) The BSCS project, initiated by Schwab, is one of the main legacies of this author. It still continues to develop inquired based curricula today. The BSCS curricula has been considered as the “most successful of the new high school science curricula” (Schymansky, 1984 in Bybee, 2010). Developments of Schwab’s work exist not only through BSCS. Other researchers have directly adapted the model produced by Schwab. The model of inquiry produced by Rezba et al., (1999) is an example of this.

The main difference in the new developments of inquiry learning is that they have somewhat demystified the belief that students can learn as scientists. These new adaptations of inquiry are more adapted to the educational setting (Hmelo-Silver et al., 2007) Therefore, inquiry learning is organized around relevant, authentic problems or questions. It emphasises collaborative learning and activity. Furthermore, students are cognitively engaged in sense making, developing evidence-based explanations, and communicating their ideas. The teacher plays a key role in facilitating the learning process and may provide content knowledge on a just-in-time basis (Hemlo- Silver, 2007). Originating from the models of Schwab (1963) and Suchman (1960), inquiry learning can be organised into a series of phases or steps.

Bell et al., (2010) analysed ten recent models of inquiry learning and defined the similar steps that these models follow. These steps are presented in the table 4.4.
The model of inquiry represented in this table presents, in greater detail, all the categories involved in a complete inquiry activity. The nine categories, or main inquiry processes, represent the ideas about inquiry held by the ten models (Bell et al., 2010). The order is not fixed as students can go through the steps in different ways and return to them (Windschitl, 2004).

This section presented four models of learning used in science education and their recent applications: Inductive Thinking, Advance Organizers, Biological Science Inquiry Model and Inquiry Training. The next section analyses the four learning models in relation to the dichotomies defined in Chapter three. This will allow the development of the conceptual and pedagogical dilemmas that will be used in the interview methodology to address the aim of the research.

4.3. Dialectic and constructive analysis of teaching models for science education

The dialectic and constructive dichotomies defined in section 3.4 of Chapter three are conceptual tools used to analyse the four learning models presented in the previous section. This dialectic constructivist lens is used because, as concluded in Chapter two, reform in science education and outreach is grounded in the principles of constructivism. Specifically the education models are going to be compared according to the conceptual dichotomies Autonomy/Dependency, Induction/Deduction, Creativity/Guidance and Simplicity/Complexity. The science education models are presented within the dichotomies below to illustrate a pedagogical application of each of these dichotomies. This application is particularly relevant as reform in science education and outreach is
grounded in principles of constructivism. Therefore it is important to understand how the different models that are used in science education are positioned according to these dichotomies.

As discussed in Chapter three the dichotomies consist of two opposing concepts, and this allows the observer to position themselves at some point between either end of the continuum (Joyce-Moniz and Barros, 2005). This has a methodology application for data collection, explored later in this thesis. If opposing models of teaching and learning are used in this dichotomic way, it allows practitioners to identify their own preferred model in relation to the two extremes. That is, the continuum allows one to locate their teaching and learning practice in relation to their conceptual opponents (Joyce-Moniz, 1993; Joyce-Moniz and Barros, 2005).

This section analyses each of the teaching models for science education detailed above with respect to the different dialectic dichotomies. In a sense it draws a pedagogical application from each of the conceptual dichotomies. The models are then graphically displayed.

4.3.1. Autonomy/Dependency

All models more or less explicitly place student’s autonomy in the learning process as an ultimate aim to be achieved. Nevertheless, they differ in relation to the degree of autonomy the student should have, and on the degree of control that the teacher should have. They have different conceptions about how much epistemological and experiential autonomy should be given to the student (Joyce and Weil, 2000). In the previous section the ‘teacher-student role’ was described when presenting each of the models. The teacher-student role describes the degree of autonomy a student has in the learning process (Joyce and Weil, 2000). This role is used to draw comparison between the four science education models in relation to the dichotomy Autonomy/Dependency.

The position of the models in relation to the dichotomy is represented in figure 4.5 below. The models that more explicitly emphasize the autonomy of the student are the inquiry models (Inquiry Training; Biological Science Inquiry Model). The one that supports the inductive way of thinking positions itself in the middle of the continuum (Think Inductively). The Advance Organizers model is the one closest towards dependency. The reasoning for their positioning in this dichotomy is explained below. This reasoning is grounded in the discussion of the teacher-student role.

Figure 4.5 Position of the learning models along the continuum Autonomy/Dependency

Two models identified in the previous section support an inquiring mode of learning: Inquiry Training and Biological Science Inquiry Model. In both, the teacher orders a highly structured sequence of learning tasks, which are evident in the different phases of each model. Nonetheless, since the beginning, the teacher prompts student autonomy (Joyce and Weil, 2000).

In Inquiry Training, the system is highly structured and controlled largely by the teacher. However, it is stated in the model, that the teacher and student participate as equals where relevant
ideas are concerned (Joyce and Weil, 2000). The Biological Sciences Inquiry model states that the teachers’ task is to emphasize the process of inquiry and incentivise students to reflect on it, thus increasing their epistemological autonomy (Joyce and Weil, 2000). The emphasis on the student’s autonomy is greater in phases two, three and four of the Biological Sciences Inquiry model. In phase two: *structure the problem*; it is the student that identifies a difficulty in the investigation. In phase three, students identify the problem in the investigation. And in phase four, it is the student that speculates about ways to clear up the difficulty.

*Thinking Inductively* is less explicit in terms of emphasising student autonomy. In this model, the teacher is the initiator of phases, and the sequence of activities is determined in advance (Joyce and Weil, 2000). Therefore, the teacher begins from a controlling, though cooperative, standpoint. Furthermore, during the initial part of the three strategies, the teacher retains most of the control of the lesson. Nonetheless, in later stages, the teacher releases some of the epistemological control (Taba and Spalding, 1962). Therefore, the student obtains a certain degree of epistemological control for judging, deciding and concluding. This is when the students assume greater control and consequently the teacher offers progressively less direct support. Therefore, the epistemological autonomy of the student is increased.

In the continuum between autonomy and dependency, the model *Advance Organizers* is closest to the pole of a student’s dependency imposed by the teacher, as seen in figure 4. In this model, the teacher has the epistemological authority. From the beginning, the teacher imposes a level of highly structured control and retains it throughout the three phases of the model (Joyce and Weil, 2000). It is the teacher that plays the role of lecturer and explainer. The main purpose is to help the student acquire subject matter. Moreover, Ausubel rejects the notion that direct instruction necessarily leads to rote memorization, passive activity or non-meaningful learning (Ausubel, 1963). The only phase where the student has more autonomy is in phase three, where students initiate comments and questions.

### 4.3.2. Induction/Deduction

Some of the learning models express an inductive path to acquire knowledge, from concrete facts to general concepts. These models are *Thinking Inductively*, *Inquiry Training*, and *Biological Sciences Inquiry* model. The remaining model, *Advance Organizers*, argues for a deductive path to acquire knowledge, from concepts to their attributes. The position of the models in relation to this dichotomy is presented in figure 4.6. This positioning is explained below.

**Figure 4.6 Position of the learning models along the continuum Induction/Deduction**

As discussed in section 4.2.1, the *Thinking Inductively* model is purely inductive. It is composed of three inductive thinking tasks and three teaching strategies to induce those tasks.

In *Inquiry Training*, the objective is to help students develop the skills necessary to raise questions and search out answers stemming from their curiosity (Suchman, 1960). This is an
inductive strategy (Joyce and Weil, 2000). The Biological Sciences Inquiry model uses a narrative of inquiry. Its aim is for students to develop knowledge from the interpretation of data (Schwab, 1963). Therefore, Biological Sciences Inquiry also follows an inductive model of teaching. The experimental work is organized in order to incentivise students to investigate problems, rather than the simple reproduction of content. The student is asked to generate hypotheses, interpret data, and develop concepts. This is seen as an emergent way of interpreting reality (Schwab, 1963).

The Advance Organizers model represents a purely deductive approach. For instance, the phase expository organizers provide a basic model for class inclusion. In it, there is a classificatory succession of classes, sub-classes and elements. The sequence of instruction is built from the top down. The most inclusive concepts, principles and propositions are presented first (Ausubel, 1963). Whereas inductive approaches lead students to discover concepts, the advance organizer provides concepts and principles to the students directly.

4.3.3. Creativity/Guidance

All teaching methods include reference to some form of cooperation between teacher and student. Co-construction of knowledge is the explicit dialectic attitude of the teacher to help the student to engage and proceed with the learning process (Joyce-Moniz, 1993). The models differ in the level of co-construction. Figure 4.7 represents the position of the models along the continuum, which is now explained.

In the initial stage of each of the models, the teacher is directive but dialectically active. In the latter phases of the learning process, the teacher changes the confronting attitude to a more experiential one of working with the student. This results in a more balanced epistemological exchange, for a participative construction of learning contents (Joyce-Moniz, 1993).

Figure 4.7 Position of the learning models along the Creativity/Guidance continuum

![Position of the learning models along the Creativity/Guidance continuum](image)

The inquiry models are the ones that leave the construction of knowledge more open to the student. As described in section 4.2.3 the teacher adopts the role of a collaborator of student’s work in the inquiry models. The balance of epistemological and operational shared power leans more so towards student’s autonomy. In the biological sciences inquiry model, a cooperative, rigorous climate is desired by the developers of the model (Schwab, 1963).

The Thinking Inductively model argues for co-construction when it states that the cooperative atmosphere of the classroom results in a good deal of pupil activity (Taba and Spalding, 1962). In this model, the co-construction draws a greater emphasis to the role of the teacher since it is her/him that is the initiator of all the steps (Taba and Spalding, 1962). Nevertheless, as seen in section 4.2.1, in each of the three strategies, the student is left to construct her/his view of concepts,
to interpret and apply it (Taba and Spalding, 1962). Therefore, a degree of student lead construction is present.

The *Advance Organizers* model’s co-constructive nature is clearer in phase three: strengthening the cognitive organization. It is the only phase that is initiated by both teacher and student. It is also in this phase that the student is more active through active reception learning. In the first two phases, the teacher directs the construction of knowledge by presenting the advance organizer and learning material. Therefore, this model is the one in which the co-construction is more teacher led.

### 4.3.4. Simplicity/Complexity

All models discuss the student’s learning progression from conceptual and operational simplicity to complexity. Nonetheless, some models make this progression clear whilst others do not. Figure 4.8 represents the position of learning models within this dichotomy. The progress towards complexity is more explicit in the model *Advance Organizers*. In the other models, the progress is less explicit. *Thinking Inductively* is the less explicit one. The justification for this positioning in Figure 4.8 is outlined below.

![Figure 4.8 Position of the learning models in the continuum Simplicity/Complexity](image)

In *Thinking Inductively*, the student’s progress to more complex ideas is established in terms of internalization of concepts. The teacher can assist the processes of internalization and conceptualization by stimulating the students to perform complex mental operations. Furthermore, the teachers offer progressively less direct support.

In both the *Inquiry Training* model and the *Biological sciences inquiry model*, there is not a clearly identified objective in relation to complexity, but the models emphasize the student as a scientist involved in more complex inquiry activities. Therefore, one can infer that those models defend the principle of progression from simplicity to complexity. In the *Inquiry Training*, it states that the student will become increasingly conscious of their process of inquiry. In the *Biological Sciences Inquiry Model* the essence of the model is to teach the student to use techniques similar to those of research biologists. The *Biological Sciences Inquiry Model* is more explicit than *Inquiry Training* in the progress towards complexity, as the sets of invitations to inquiry become more complex, leading the students to more complex concepts.

The model *Advance Organizers* objectifies progression towards complexity. It does it in terms of a hierarchy of learning tasks, increasingly inclusive and complex, carried out by the student. Ausubel makes a parallel between the way subject matter is organized and the way people organize knowledge in their minds. Ausubel (1963) states that an academic discipline has a hierarchically
organized structure of concepts. Therefore, the top level of each discipline includes very broad, abstract concepts. These abstract concepts include more concrete concepts at lower stages of organization. The model presents a progressive differentiation.

4.3.5. Combining or crossing continuums

The dialectic dichotomies were used to trace epistemological and operational positions in the continuums. The one-dimensional dichotomies can be crossed two on two, creating a bi-dimensional figure. The following figures each represent a crossing of two dichotomies of criteria. The advantage of the framework is that it allows for the analysis of conceptual and methodological options of the different models. The 4 continuums could be crossed with each other. Figures 4.9 and 4.10 represent two possible crossing of continuums.

Figure 4.9 Models of teaching in crossed continuums Simplicity/Complexity Autonomy/Dependency
Figures 4.9 and 4.10 reveal the analysis of the positioning of each of the four science education pedagogical models according to the dialectic dichotomies. It provides a summary of the analysis made in the previous sections. Figure 4.9 emphasizes the comparison between Autonomy/Dependency and Simplicity/Complexity. Models in the bottom left corner emphasize autonomy but do not explicitly progress towards complexity. Models in the top right corner emphasize dependency and make an explicit progression towards the construction of knowledge. Figure 4.10 emphasizes the comparison between Induction/Deduction and Creativity/Guidance. Models on the bottom right corner emphasize induction and the construction of knowledge is left more open for the student. Models on the top left emphasize deduction and the teacher controls more the co-construction of knowledge.

The dialectic and constructive dichotomies Autonomy/Dependency, Induction/Deduction, Creativity/Guidance and Simplicity/Complexity provide us with a continuum framework within which to situate each of the prominent models of science education.

4.4 Chapter Summary

This Chapter built on the conclusions of Chapters two and three and analysed models of teaching relevant in science education. This was carried out as Chapter two identified the need for science outreach to achieve a deeper connection with formal education and therefore formal teaching methodologies. The models were analysed using the conceptual constructivist dialectic dichotomies presented in Chapter three. Constructivist criteria were selected as both science education and outreach emphasize constructivism as a philosophical basis. These models provide the contextualised basis for the pedagogical dilemmatic cases that are going to be presented in the next Chapter.

The Chapter started with the identification of four models of learning, inductive thinking, Biological Science Inquiry Model, Inquiry Training and Advance Organizers. These models emanated from the framework of Joyce and Weil (2000). Current applications in science education were discussed. Finally, the models of learning were analysed according to each of the dialectic dichotomies revealing how they are positioned in the continuum between the opposing concepts.
This Chapter concluded phase one of this study, the literature review. Phase one started in Chapter two, which analysed science education and science outreach, and concluded that science education reforms are guided by constructivist epistemology. Furthermore, two main gaps were identified: understanding the role of science outreach in primary level by comparing science outreach and education according to constructivist conceptualization; the need for a stronger methodological basis for science outreach and the role of curricular models of science education for this purpose. Therefore, Chapter three explained constructivism and discussed a constructivist dialectical model that defines conceptual dialectic dichotomies that are relevant for the comparison of science education and outreach. Chapter four further explored and contextualised these dichotomies by using them to analyse models of learning relevant to science education. This allows the development of the conceptual and pedagogical dilemmas that will be used in the interview methodology, which is presented in Chapter five. Phase two of this research starts in the next Chapter, which explains the mixed methods research approach followed by this study.
Chapter Five: Method and methodology
5.1 Introduction

This Chapter presents the methods and methodology employed in this study. It starts by describing research methodology this study follows. Then it presents the interview and survey instruments, which are core to the mixed methods approach used. Figure 5.1 presents a visual overview of both research instruments.

Figure 5.1 Research methods

<table>
<thead>
<tr>
<th>Constructivist learning environment Survey</th>
<th>Semi-structured interview</th>
</tr>
</thead>
<tbody>
<tr>
<td>Completed by:</td>
<td>Completed by:</td>
</tr>
<tr>
<td>• 149 teachers</td>
<td>• 31 teachers</td>
</tr>
<tr>
<td>• 81 science outreach practitioners</td>
<td>• 29 outreach practitioners</td>
</tr>
<tr>
<td>19 five-level liickert questions</td>
<td>20 to 30 minutes interviews with 6 fixed alternative questions followed by open questions</td>
</tr>
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The survey instrument is a standardised questionnaire, the Constructivist Learning Environmental Survey, adapted within the context of this study. It was completed by 149 teachers and 81 science outreach practitioners. The semi-structured interview involved the presentation of a series of animated videos of six dilemmas (three conceptual, three pedagogical). Each of the six dilemmas were followed with one fixed alternative question and a few open questions. Participation involved 31 primary level teachers and 30 science outreach practitioners. The Chapter starts with the description of the research methodology.

5.2. Research Methodology

5.2.1 Pragmatism, Mixed Methods and Research Design

This study follows a research paradigm defined as dialectical pragmatism. This section starts by explaining the dominant paradigms in education research and why dialectical pragmatism is the epistemological root of this study. It then discusses why this research employs a triangulation design convergence model.

Research paradigms are defined as the set of beliefs, values, and assumptions that a community of researchers have in common about the nature and conduct of their research (Johnson and Onwuegbuzie, 2004, p.24). Educational research has been dominated by two research paradigms: positivism and constructivism (Johnson and Onwuegbuzie, 2004). Positivism is a “doctrine applied to the method of science, which consists of a set of principles about how scientific (i.e. valid and reliable) knowledge could be acquired” (Hart, 1998, p.82). It is a view of social science in which there is much respect for quantification (Lather, 2010). To achieve quantified results positivists use objective methodologies that provide generalizable, reliable and replicable findings (Stevenson, 2008, p.454). Constructivism is the qualitative research paradigm that opposes positivism. Constructivism contends that multiple-constructed realities abound and that time and context-free generalizations are neither desirable nor possible (Lather, 2010). The constructivist paradigm argues that research is value-bound and thus impossible to fully differentiate causes and effects (Johnson and Onwuegbuzie, 2004, p.14). It is important to distinguish between constructivism as a research paradigm and constructivism in education. Constructivism in education is rooted in the wider ontological and epistemological constructivist paradigm (Constantino, 2008).
Nevertheless, constructivism in education specifically “deals with how people learn and, thereby, how instruction should be carried out” (Constantino, 2008, p.118). It is, therefore, a development of the wider constructivist paradigm to theories of teaching and learning.

The two research paradigms, positivism and constructivism, are often considered incompatible. According to this view, the methodologies that reflect each should not be mixed (Greene, 2007). The third paradigm, pragmatism, opposes this view as it argues the compatibility thesis (Howe, 1988). The compatibility thesis sustains that quantitative and qualitative methods can be combined productively in a research study. Pragmatism aims to find a middle ground between philosophical dogmatism and scepticism. The pragmatic objective is to find workable solutions to philosophical problems, thus rejecting binary choices (Johnson and Onwuegbuzie, 2004). Pragmatism translates into research as: “choose the combination or mixture of methods and procedures that work best for answering your research questions” (Johnson and Onwuegbuzie, 2004, p.17). A further refinement given to classic pragmatism associated with mixed methods research is dialectical pragmatism (Greene, 2007; Teddlie and Tashakkori, 2009). Dialectic pragmatism emphasizes that “pragmatism for mixed methods takes quantitative and qualitative methods seriously but then develops a synthesis for each research study” (Teddlie and Tashakkori, 2009, p.73).

This study follows the dialectical view of pragmatism. As discussed in previous Chapters, a dialectical view underpins this research. The research involves different populations, teachers and outreach practitioners, with complex realities, objectives and desires, as discussed in Chapter two. Therefore, the dialectical mixing of methods is relevant to answer the research questions of this research. Using mixed methods allows us to address these complex realities as it employs different research designs and methods (Bryman, 2008). Furthermore, as this study uses different methods, it employs deductive and inductive logics to address the two main research questions (Johnson and Onwuegbuzie, 2004).

5.2.1.1 Research design in mixed methods

The use of mix methods under a pragmatic philosophy can follow different designs. Therefore, different typologies of mixed method designs have been developed since the emergence of this field (Teddlie and Tashakkori, 2009, Kington et al., 2011). Greene et al. (2007) typology is based on the objectives of mixed methods. In this study, methods are combined with the objective of triangulation.

Triangulation seeks convergence and corroboration of results from different methods and designs, when applied to studying the same phenomenon (Greene, 2007). Triangulation is present in this study because both quantitative and qualitative methods are used to explore the same phenomenon: teachers’ and science outreach practitioners’ understanding and perceptions of constructivist science teaching pedagogy.

According to Creswell and Clark’s (2007) typology, this study follows a mixed methods design through a triangulation design and convergence model, as represented in Figure 5.2. Quantitative data was obtained through the Constructivist Learning Environment Survey (CLES). Concurrent with this, qualitative and quantitative data was obtained through a semi-structured interview format.
Parallel mixed methods are considered powerful as they offer rich data (Teddlie and Tashakkori, 2009) Nevertheless, three challenges have been identified in parallel mixed methods, as indicated in figure 5.3 (Teddlie and Tashakkori, 2009) below. Also Kington et al., (2011, p.19) identify a further challenge: “the time demands involved in implementing the design and facilitating the dialogue between methods”.

Two strategies were followed to overcome these challenges. Firstly, a mathematics professor assisted in the sampling design and in the statistical analysis of the survey. Secondly, two experienced researchers collaborated in the coding process of participants’ responses to the semi-structured interview. These strategies are further described in the analyses Chapters (Chapter six and Chapter seven). After justifying the dialectic pragmatic epistemology and the triangulation convergence model, the next section details the data collection methods employed.

5.3 Method

5.3.1 Data collection: Semi-structured interview

This section details the semi-structured interview developed for this study. The interview was designed to analyse the explanations and understanding of teachers and outreach practitioners when responding to conceptual and pedagogical dilemmas in science teaching and learning. This section starts by describing Interview as a general research method. It continues with the discussion of the specific design followed, explaining why dilemmas and animations were used. Next, it describes the interview protocol and implementation.

5.3.1.1 Semi-structured interview

An interview is a conversational practice where knowledge is produced through the interaction between an interviewer and an interviewee or a group of interviewees (Brinkmann,
Cohen et al., (2007) defines the three purposes for a research interview: Firstly, the interview can be the principal source of information of the research, having direct relation to the research objectives. Secondly, the interview can be used to test hypothesis, suggest new ones or to help identify variables and relationships. Finally, it can be used in conjunction with other research methods in a multi method research, as in the case of this research.

Interviews are an appropriate research method for when “the objective is to gain access to ideas, thoughts and emotions” (Bloland, 1992, p. 2). This research has the core objective of disclosing teachers and science outreach practitioners’ understanding when analysing conceptual and pedagogical dilemmas in science teaching. Interviewing is the method that can best serve this purpose as it can reveal research participants thinking (Bloland, 1992).

The type of interview chosen for this research is a mix between the standardized open interview and the interview guide approach, a semi-structured interview (Wellington, 2007). The topics and issues to be covered were specified in advance and some of the questions had a pre-determined sequence. As the interview progressed, salient issues that started to appear in relation to how the participants analysed the dilemmas were explored and the interview followed a less structured level. The less structured level explored the reasoning behind the answers given to the pre-determined questions. For instance, when teachers mentioned issues of time and curriculum the researcher asked if they could give examples and elaborate more. To achieve this, a degree of elaboration probing was present as per the guidelines of Wellington (2007).

The semi-structured interview has often been considered the most valuable in qualitative research (Wellington, 2007). Semi-structured interviews overcome the problems inherent to the unstructured interviews but avoid the inflexibility of the structured interview (Wellington, 2007). Unstructured interviews make it difficult to analyse and compare data between different participants. For that reason, an unstructured interview would not allow a comparison between teachers and outreach practitioners. A structured approach would also impair the objectives of the research, as it would be too impersonal and mechanical. A structured approach wouldn’t permit understanding the research participant’s reasoning and opinions. Therefore, a semi-structured approach was selected. The semi-structured approach allowed the responses of the research participants to be compared. At the same time, it gave space for respondents to reason and to explain their choices.

After discussing why this research used a semi-structured interview, the next section describes the methodological basis of the interview.

5.3.1.2. Rationale of the interview

The conceptual dichotomies that guide the interview are explored in the previous Chapters, specifically, Chapters three and four. There are three conceptual and three related pedagogical dichotomies, as seen in figure 5.4. They form the basis of the dilemmatic cases that are presented to the research participants.
The following section describes the specific methodological tools that are core elements of the interview process. First, the use of dilemmas followed by the justification of the use of dramatized animation is explained.

### 5.3.1.2.1 Design of the instrument: Dilemma as a method, conceptual and pedagogical dilemmas

One of the main objectives of this study is to analyze how primary level teachers and outreach practitioners understand conceptual and pedagogical dilemmas in science teaching and learning. The reasoning behind the choice of the dilemmas is now explained.

The dual nature of this research encompasses the first rationale for employing the use of dilemmas in this research. This dual nature is well supported in other studies of inquiry learning in science education: a ‘rationalistic’ (i.e., pre-meditated) and ‘naturalistic’ (i.e., emergent) quality (Bencze and Bowen, 2009; Harwood et al., 2006). It is rationalistic in that the main focus is on participants’ choice of the type of science education they value and promote. However, it is also expected that various themes would emerge whilst the research participants explained their reasoning, giving this research a significant naturalistic character. The use of dilemmas builds on previous research which used classroom and dilemma cases to investigate challenges faced by teachers. Yoon and Kim’s (2009) research focused on having teachers illustrate and explain dilemmas they face in practice. Tippins et al.’s (1999) study asked teachers to analyse selected dilemmas throughout a methods course. Other research studies, such as Kington et al., (2011, p.11), in spite of not specifically using dilemmas, use the repertory grid interviews in which teachers explore “conflicting viewpoints and (underlying) claims with regard to effective teaching”.

The second reason for employing dilemmas is the dialectical nature of the research. This study aims to unravel the tensions and contradictions faced by practitioners when making choices around planning and teaching lessons. For this research, contextualized and specific dilemmatic cases were presented to teachers and outreach practitioners. The cases followed the classic definition of dilemma in which two conclusive arguments (dichotomy) are presented in opposition (Tillema and Kremer-Hayon, 2002). Research participants were first asked to choose between the two polar arguments, as illustrated in figure 5.4. Each polar argument was presented to them through a video format, and they were then encouraged to identify how they would position themselves with respect to either argument. The interview continued with questions that aimed to elicit the reasoning behind their initial choice. The dilemma framework can lead the research participants to interrogate their own beliefs and question institutional routines (Windschitl, 2002, p.134). Therefore, it can produce contextualized reflection, unravelling tensions and contradictions.

<table>
<thead>
<tr>
<th>Conceptual dichotomies</th>
<th>Pedagogical dichotomies</th>
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<tbody>
<tr>
<td>Autonomy</td>
<td>Open inquiry</td>
</tr>
<tr>
<td>Dependency</td>
<td>Guided Inquiry</td>
</tr>
<tr>
<td>(McRobbie and Tobin, 1997; Davis, 2003)</td>
<td></td>
</tr>
<tr>
<td>Induction</td>
<td>Inductive activity</td>
</tr>
<tr>
<td>Deduction</td>
<td>Deductive activity</td>
</tr>
<tr>
<td>(Reid, 2011; Kirschner et al., 2006)</td>
<td></td>
</tr>
<tr>
<td>Creativity</td>
<td>Student led-construction of object</td>
</tr>
<tr>
<td>Guidance</td>
<td>Teacher-led construction of object</td>
</tr>
<tr>
<td>(Beghetto, 2007; McRobbie and Tobin, 1997)</td>
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</tr>
</tbody>
</table>

Activity selected to be presented according to the dialectical poles:
- Colored Plant (DPS, 2012) (from the curricular strand: investigate factors that affect plant growth)
- Build a magnetic car (DPS, 2012) (from the curricular strand: learn that magnets can push or pull different materials)
- 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)
Two types of dilemma were presented, conceptual and pedagogical, and these are elaborated upon below.

**Conceptual dilemmas**

The conceptual dichotomies that form the basis of the conceptual dilemmas were explained in Chapter three. These dichotomies are Autonomy/Dependency, Induction/Deduction and Creativity/Guidance. In order to present the participants with each of these dichotomous choices, theoretical explanations/quotes were selected from relevant literature and presented in the form of a short video clip. The opposing perspectives were based on claims obtained from science education journals and were first presented in Chapter three. This methodology is congruent with previous studies in which teachers analysed claims from researchers about inquiry learning (Bencze and Bowen, 2009) or claims that portray conflicting viewpoints regarding effective teaching (Kington et al., 2011). In the current study, the perspectives were presented in the form of a dilemmatic reflection by a teacher through video format (Appendix A). The dilemmatic reflection is used to better facilitate the dialectical thinking of the research participants. This reflection allows the research participants to engage in inductive and deductive thinking (dialectically) when confronted with the dichotomies (Bencze and Bowen, 2009). To promote deductive thinking, the research participants are explicitly presented with opposing perspectives. Afterwards, they can engage in inductive thinking, as they develop claims about the dilemma, when relating to their own practice. By presenting the participants with a binary choice, it engaged them in a dialectic reflection. It was this dialectic reflection that allowed the unravelling of the tensions and contradictions faced by practitioners when having to make choices during their practice (Yoon and Kim, 2009) and the understanding of the perceptions of the participants of constructivist science teaching pedagogy in order to improve science education/outreach practice in Ireland.

Apart from the conceptual dichotomies forming the conceptual dilemmas they also informed the pedagogical dilemmas, which are presented in the next section.

**Pedagogical dilemmas**

Although conceptual dilemmas are core to understanding epistemological positions, pedagogical ones are of no less relevance. Pedagogical dilemmas deal with the concrete (Windschitl, 2002). They are contextualized activities that teachers and outreach practitioners develop with their students. This section details the pedagogical dilemmas used in this study.

The pedagogical choices teachers make in their teaching may not be in accordance with their conceptual positions. This is what has been called the dichotomy beliefs/practice, in which teachers’ beliefs are often not reflected in their practice (Savasci and Berlin, 2012). By presenting both, it is possible to compare teachers and outreach practitioners’ views of their conceptual and pedagogical beliefs.

The pedagogical dilemmas (as illustrated in figure 5.5) were developed in two steps. First, they each emerge from their conceptual counterpart. Each of the pedagogical dilemmas presented is aligned with one of the conceptual dilemmas. Second, in order to contextualize them in practice, the dilemmas take into account the Irish curriculum and activities prescribed in it, as well as the relevant science education teaching and learning models presented in Chapter four. The three pedagogical dichotomies that form the pedagogical dilemmatic cases are described, following the figure below.
Open Inquiry vs. Guided inquiry

The pedagogical dichotomy Open/Guided Inquiry emerges from the dialectics between autonomy and dependency analyzed in Chapter three. As discussed in Chapter four, inquiry learning is the most cited and debated pedagogy in science education (Blanchard et al., 2010). Moreover, Chapter two demonstrated that the Irish primary level curriculum stresses inquiry learning as a methodology (DES, 1999). The inquiry activity that was used to build this dilemmatic case is presented in Appendix B. The activity is chosen from the strand unit ‘plant and animal life’ as it is one of the most dominant strands in the primary science curriculum. The specific activity is ‘flower power’ (DES, 1999). As shown in Appendix B, the activity can be presented in dilemmatic fashion using the dichotomy Open/Guided Inquiry. In the open inquiry option, the teacher begins by explaining what is being investigated, then passes over the control to the students. The students define the problem, plan the investigation according to the materials they have, carry it out and try to reach a conclusion. Therefore, in the open inquiry option students have a high level of autonomy. In the guided inquiry version, the teacher explains the problem and gives the students the steps they need to perform the experiment. The students then conduct the experiment and try to reach a conclusion with structured teacher questions. In the guided inquiry option students are more dependent on the teacher. The pedagogical dichotomy Open/Guided Inquiry emerges from the conceptual dichotomy Autonomy/Dependency.

Inductive activity vs deductive activity

This pedagogical dichotomy emerges from Induction/Deduction, as analysed in Chapter three. In Chapter two it was demonstrated that the Irish curriculum and science education reforms favour changing school science-teaching pedagogy from mainly deductive to inductive practices (European Commission, 2007, DES, 1999). Chapter four demonstrated that teaching in science can follow a deductive model (Ausubel, 1963) or an inductive one (Taba and Spalding, 1962). The activity that was used to build this dilemmatic case is presented in Appendix C. The activity comes from the strand unit ‘Learn that magnets can push or pull different materials’ (DES, 1999, p. 347). This strand is part of the strand unit ‘Energy and forces’, the most developed strand unit in the Irish curriculum. The activity that the curriculum proposes for this strand is: build and play with a magnetic car
(Appendix C). As seen in Appendix C, this activity is presented in two opposing ways (dilemma). The first option follows a deductive path. Firstly, the scientific concept of magnetism is explained, following the premise of the advance organizer model. An advance organizer is a tool used to introduce a lesson and illustrate the relationship between what the students are about to learn and the information they have already learned (Ausubel, 1963). In a sense, it presents students with a cognitive organisational framework for connecting previous learning with new learning. The advance organizer is a preliminary statement of concepts that are wide enough to encompass the new knowledge to be apprehended, in this case magnetism (Ausubel, 1963). After, the students attempt to apply that concept by playing with the magnetic cars and reasoning how they can move, combining their knowledge with play. The second step follows an inductive approach. The teacher presents an example that demonstrates the concept of magnetism, the magnetic car (Taba and Spalding, 1966). The students, through play and by analysing how the magnetic car works, induce and as such, generate an understanding of the concept of magnets.

**Student-led/teacher-led construction of an object**

The pedagogical dichotomy student-led/teacher-led construction emerges from Creativity/Guidance, the conceptual dichotomy analyzed in Chapter three. Chapter two revealed the significance given to creativity in educational policy documents including the Irish primary level curriculum (DES, 1999). Chapter four revealed that different models of teaching permit different levels of creativity depending on the level of co-construction between teacher and student. A student-led construction allows for a greater development of creative thinking (Beghetto, 2007). The activity that was used to build this dilemmatic case is presented in Appendix D. The strand of the curriculum where the activity is included is ‘explore how levers may be used to help lift different objects: design and make a toy using a lever’ (DES, 1999). This strand is part of the strand unit ‘Energy and forces’, the most developed strand unit in the Irish curriculum. The curriculum suggests a specific activity referred to as Wag the dog (Appendix D) for teachers to develop in this strand.

The activity is presented within this research project in two distinct methodologies, each with opposing teaching scenarios: a student-led and a teacher-led construction. Both options start with a background information sheet, which is read to the students, and explains what levers are. After, there is a paper lever toy for students to build. In the student-led construction, students build their own toy. This increases uniqueness and therefore creativity (Beghetto, 2007). In the teacher-led construction the ‘what’ and ‘how’ to build the toy is pre-set, which diminishes the creative aspect of the construction.

**Animated dramatization as a media**

Videocases have been described as tools for contextualizing teaching and learning, and ways of thinking about these processes (Abell et al., 1998). They are a virtual world that "reduces the complexity of teaching into a manageable story situated in a specific context" (Abell and Cennamo, 2004, p. 103). In this study, video animation was used to present the six dilemmas.

Video and animation technologies can be useful for research on teacher thinking and decision making (Chazan and Herbst, 2012). Videocases were developed by previous studies in a way that supports the specific method used in this research. For instance, Abell et al., (1998) reports that, in their study, science teachers processed and interpreted videocases representing dilemmas in elementary science.

This research used digitally animated cases instead of video records. Xtranormal was the software program used to build the animation. A screenshot of the videos is presented in figure 5.6.
Animation was chosen because the use of video records of real classrooms can have critical problems (Chieu et al., 2011). It is reported that video records may direct too much attention to idiosyncratic characteristics of individuals or of the setting (Herbst et al., 2011). Animations can eliminate the elements too particular to individuals that are often present in video records (Chieu et al., 2011). Therefore, animations help viewers focus on critical moves of the teacher and students (Chazan and Herbst, 2012). In particular, they allow teachers to project features of their own settings onto the characters in the screen. This projection invites practitioners to propose alternatives to the animated teacher’s actions (Chieu, et al., 2011; Herbst et al., 2011). Additionally, teachers may feel more comfortable criticizing the actions of cartoon teachers than criticizing the actions of real teachers (Chieu et al., 2011).

Herbst et al. (2011) introduce two concepts that reveal another argument in favour of the use of animation to represent classroom situations. The authors classify representations of teaching practice by using the dimensions of temporality and individuality. Temporality is the extent to which the representation reproduces for the viewer the passing of time in classroom interactions. Individuality is the extent to which the representation reproduces for the viewer the deployment of individuality in characters and setting in classroom interaction. A written case has low temporality and individuality whereas an unedited video has high temporality and individuality. Animations, offer a better ratio between temporality and individuality. Animations immerse the viewer in a temporality closer to that of a real classroom but offer an experience of individuality in between that of video and text.

Two different types of videocases were used in this research. First, an animated conversation between teachers is presented whereby they discuss strategic and tactical decision making in the classroom, the conceptual dilemmas. Each of the three conceptual dilemmas are portrayed using this format. Chazan and Herbst (2012) recommend animation to represent this type of situation. The same question could be ethically problematic in video of a real classroom (Chazan and Herbst, 2012). The authors argue that following the videocase snippet, the researcher can then raise the question of why teachers tend to act/not to act in the way portrayed in the animation. The second type of videocase used in this research presented two alternative actions for a science activity, the pedagogical dilemmas. Each of the three pedagogical dilemmas are presented using this classroom based activity. Chazan and Herbst (2012) consider that an advantage of the unreality of
animations is that it allows for the creation of a set of alternative actions in opposition to videos of real classrooms.

After enumerating the reasons for the use of animation, the next section describes the scripts used for both the conceptual and pedagogical scenarios, along with the interview guide.

5.3.1.3 Scripts and Interview Guide

The interview guide followed the guidelines of Tuckman (1978) and Patton (1980). The interview started with the briefing of the research participant as to the nature and purpose of the interview. Next, the researcher requested to audiotape the research participant’s responses. The interview continued with easy and non-controversial questions dealing with demographic and background information. Finally, the interview proceeded to the presentation of the dilemmas.

A fixed alternative question followed the video presentation of each dilemma (Cohen et al., 2007). The fixed alternative question is chosen to promote dialectical thinking. The research participants were faced with two alternatives (thesis and antithesis) in order to promote dialectical thinking. Fixed alternative questions allow for a more efficient analysis of the responses. They permit a greater uniformity of measurement and reliability, with easier coding (Kerlinger, 1973). Nevertheless, fixed alternative questions also have disadvantages. The disadvantages include the superficiality of the questions, possibility of irritating the research participants who find none of the alternatives suitable, and the possibility of forcing responses that are inappropriate (Kerlinger, 1973).

Therefore, responses to fixed alternatives were not enough to generate new insights in relation to the dilemmas. Consequently, each fixed question was followed up with a more open-ended question(s) to elicit deeper engagement with the concepts/methods. Open-ended questions are more flexible, with probing, in order engage the participant in deeper reflection about their choices and to clarify any misunderstandings. The open-ended questions may also permit unexpected or unanticipated answers that can suggest hitherto unthought-of relations or hypothesis (Cohen et al., 2007).

The method of using two types of questions was used after the video presentation of the six dilemmas. The specific scripts and questions are listed in the interview guide (Appendix E).

5.3.1.4 Piloting of the interview

Silverman (1993) emphasizes that piloting an interview is essential to enhance its reliability. The interview protocol was pre-tested with a teacher and an outreach practitioner.

The first issue reported by both respondents was the voice-over. Initially, the voice over used, which came with the software program, was a synthetic voice. Both the teacher and the outreach practitioner said that they could not relate to it. The voice over was changed with the help of two volunteer colleagues by using lip synching technology and human voices. After this alteration, the videos were shown again to the participants who found them much more relatable.

The teacher also found that some of the expressions used in the video were not common amongst teachers. Therefore, she helped with the wording of the lines, making it more relatable to the conversational tone of teachers.

The third issue was related with the less structured parts of the interview. Much of the feedback refers to the unstructured section of the interview, the open questions. However, in the pre-test interviews, at times, personal curiosity of the researcher led the interview to issues outside of the initial scope. Cohen et al., (2007) reports that, if the interviewer is not consciously aware of this, the interview can diverge away from the core objectives. The correct balancing, facilitated by
both probing and focusing was paramount in welcoming emergent issues, yet still remaining within
the initial scope of the interview

5.3.1.5 Administration of the interview

The four schools selected for the interview were initially contacted through teachers whom
the researcher knew, due to outreach work he had carried out in those schools in previous years.
After obtaining permission from the principal, the researcher went to each school and met with
teachers, asking them to be research participants. In the end, 31 teachers were interviewed from
two large schools and two small schools.

The outreach practitioners selected for interview were first contacted by email. The email
addresses were obtained from outreach departments of Irish universities. In this email, the
researcher introduced himself and asked to meet the practitioners. In this meeting, the participant
asked them to be research participants. In the end, 30 outreach practitioners were interviewed from
three Irish universities and two other institutions that carry out outreach in primary level schools.

5.3.2 Data collection: CLES survey

This section specifies the quantitative data collection instrument. The instrument used in
this phase of the research was the Constructivist Learning Environment Survey (CLES). The original
version of the CLES was designed in 1991 by Taylor and Fraser (as cited in Taylor et al., 1997). The
revised versions of the CLES (Taylor et al. 1997) were developed, based on the first version (Taylor
and Fraser, as cited in Taylor et al., 1997) with additions related to key dimensions of a critical
constructivist learning environment. The version used in this study is the shortened version of the
CLES survey as it is a proven and reliable instrument used both in the formal and informal sector of
education, as seen in Appendix F (Johnson and McClure, 2004). The CLES measures teachers’
perceptions of classroom practice (Taylor et al., 1997).

The CLES was initially developed by Peter Taylor, Barry Fraser, and Darrell Fisher at Curtin
University of Technology in Perth, Australia (Taylor et al., 1993). The CLES consisted of 28 items,
seven each in four scales – Autonomy, Prior Knowledge, Negotiation, and Student-Centredness.

The instrument was subsequently reviewed to include a critical theory perspective (Taylor
et al., 1995). The CLES is suited for this study as it has been used in a variety of studies as reported
by Johnson and McClure (2004). These include qualitative studies of the nature of science knowledge
and learning of science teachers and their students (Lucas and Roth, 1996; Roth and Bowen, 1995;
Roth and Roychoudhury, 1993), a study of science education reform efforts in Korea (Kim, Fisher and
Fraser, 1999), a study of preservice science teachers’ self-efficacy and science anxiety (Watters and
Ginns, 1994), a comparison of classroom environments in Taiwan and Australia (Aldridge, Fraser,
Taylor and Chen, 2000), a study of secondary preservice teacher beliefs (Waggett, 2001), an
investigation of the relationships between classroom environment and student academic efficacy
(Dorman, 2001). Furthermore, it has also been used to study informal science education. An example
of this is the study of the learning environments of natural history museums (Bamberger and Tal,
2007)

The CLES survey has five components as seen in figure 5.7. The description of the
components was adapted from Johnson and McClure (2004) to better reflect the content of the
specific questions.

89
Figure 5.7 Five components of the CLES survey

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Descriptors</th>
</tr>
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<tbody>
<tr>
<td>Personal</td>
<td>Extent to which science is relevant to students’ everyday out-of-school experiences.</td>
</tr>
<tr>
<td>relevance</td>
<td></td>
</tr>
<tr>
<td>Uncertainty</td>
<td>Extent to which opportunities are provided for students to learn that science is not always certain (that scientific knowledge evolves and is culturally and socially determined; that science is about asking and answering questions, but realising that the result is not always certain).</td>
</tr>
<tr>
<td>Critical voice</td>
<td>Extent to which educators feel it is legitimate and beneficial for students to question the teachers’ pedagogical plans and methods (in terms of seeking clarification about activities, identifying barriers to their learning, questioning how and what is being taught).</td>
</tr>
<tr>
<td>Shared control</td>
<td>Extent to which control for the design and management of learning activities is shared between the students and the teacher.</td>
</tr>
<tr>
<td>Student</td>
<td>Extent to which students have opportunities to explain and justify their ideas and to peer discuss/debate and test the viability of their own and other students’ scientific ideas</td>
</tr>
<tr>
<td>negotiation</td>
<td></td>
</tr>
</tbody>
</table>

The personal relevancy scale is concerned with teacher perceptions of the relevance of school science to their students’ out-of-school lives. The scientific uncertainty scale is concerned with teacher viewpoints on the nature of scientific knowledge. The critical voice scale measures teacher assessments of the extent to which students are able to exercise a critical voice about the quality of their learning activities. The shared control scale is concerned with teacher perceptions of sharing control of the classroom learning environment with students in relation to the design and management of learning activities, determining and applying assessment criteria, and negotiating social norms in the classroom. The student negotiation scale measures teacher beliefs concerning student perceptions of the extent to which they interact verbally with other students for the purpose of building their scientific knowledge within classrooms (Taylor et al., 1997).

5.3.2.1. Online Survey

Online survey is becoming a common research method in different fields of the social sciences (Raymond et al., 2008) and the science education research field is no exception (Cooper et al., 2012). Online survey was selected as the method for the quantitative stage of this research.

Two main advantages are highlighted in the literature for choosing an online survey research method. First, the answers collected are immediately saved in a computer database for processing. This reduces mistakes, time and costs (Vehovar and Manfreda, 2008). Secondly, online surveys have the benefit of self-administration. Self-administration enables respondents to complete the survey at a time, place and pace which they prefer. This can contribute to higher data quality, due to the sense of privacy and absence of interview related biases (Vehovar and Manfreda, 2008; Fricker et al., 2005; Kwak, 2002). Specifically, this research uses a web survey where respondents access and answer it through a web browser (Pitkow and Recker, 1995).

Online surveys have two main methodological potential problems (Fricker, 2008). One is related with sampling. As online surveys are usually distributed by email, this raises the concern of coverage in the population. Fricker (2008) suggests that this problem can be mitigated by sending letter-invitations for online surveys. Response rate is another problem of online surveys. A meta analytical study showed that online surveys obtain 6-15% lower response rates when compared to non-online surveys (Bosnjak et al., 2008).

Nevertheless, due to the advantages of reduced mistakes, time costs and higher data quality, this study uses an online survey. The next section describes in detail how the CLES survey was adapted.
5.3.2.2 Survey design adaptation

The software used to create the online survey was Survey Gizmo. Survey Gizmo is an online survey tool which allowed building the survey with the intended design. Furthermore, Survey Gizmo is free of charge for research students and permits exporting data directly to SPSS software package for statistical analysis. The survey was adapted from the CLES teacher version (Johnson and McClure, 2004).

The CLES survey is an instrument with established reliability and is widely used (Aldridge et al., 2000; Tsai, 2007). Nevertheless, the design needed to be adapted to an online version. Best and Krueger (2008) offer important guidelines to web survey design. The authors divide the guidelines in eight strands:

- Design
- Instrument transmission mode;
- Controlling access;
- Assigning participant to different conditions;
- Layout design;
- Response styles and formats;
- Audio visual stimuli
- Facilitating completion of the instrument

Each of the guideline strands were addressed in the survey design. Best and Krueger (2008) assert that the instrument must be uniform, and have high usability. The Survey Gizmo platform allows the design of a uniform instrument with a low level of difficulty of completion for respondents. Security in online surveys relates to two strands: control access and transmission mode. Controlling access is important to avoid ‘out of sample’ individuals completing the survey. To tackle this issue, the survey was only sent via email to the intended respondents. The instrument transmission mode selected was an email with a World Wide Web hyperlink. To prevent multiple submissions another access control method was used. The researcher looked for repeated IP addresses, as every system that uses the internet is assigned a unique IP address. No duplicate IP addresses were found. The survey used the specific layout design offered by Survey Gizmo to assure uniformity. The response style of the CLES survey is single response for all questions. The response option format selected was a radio button format. The radio button format prevents multiple responses as it limits automatically the number of categories respondents can choose (Couper and Lamias, 2002). No visual or audio visual stimuli were used in this survey as it did not bring significant value and could increase the download time, thus impairing completion rates (Couper, 2001). To facilitate the completion of the instrument a progress indicator bar was used, as seen in figure 5.8. Indication of progress is considered useful, especially for shorter survey instruments (Couper et al., 2001).
5.3.2.3 Piloting the Survey

Cohen et al. (2007) consider the wording of surveys of paramount importance. To ensure quality and effective wording of surveys, pre-testing is essential (Best and Krueger, 2008). For that reason, the survey was reviewed and analysed by a statistician, a teacher and an outreach practitioner. The feedback was ascertained in informal individual interviews, following the guidelines from Cohen et al. (2007).

Because the survey used is already a reliable and widely used instrument, the pilot-study focused on the invitation letter, the biographical question and how the questions related to outreach work. The next section describes both instruments and highlights the changes made.

5.3.2.4 The instruments: the invitation email and letter, the survey and follow up email

The invitation letter for Principals

The invitation letter structure followed the guidelines of Cohen et al. (2007). It indicated the aim of the research and its importance, assured the research participants their confidentiality would be kept, and encouraged their replies. The invitation letter is now described.

After the interviews with the three people identified for the pilot-study, some modifications were made. First, in the introduction, it was deemed useful to personalize the letter. Dear colleague was avoided, replacing it with exact names. Second, when identifying the advantages, the importance of the results to outreach work carried out in schools instead of general benefits to education was highlighted. Finally, the explanation of how the schools were chosen was changed. The initial version indicated the school was chosen by chance, which was replaced by this choice being made by selection, in hope of increasing the participant’s sense of responsibility.

The invitation email

The invitation email was sent to principals as a follow up reminder after the letter. The email was sent to outreach practitioners as the first contact. Similarly to the purpose letter, it followed the
structure and guidelines suggested by Cohen et al. (2007). The purpose letter and invitation email were very similar. Therefore, the feedback and amendments were quite similar. Nevertheless, there were specific amendments to the invitation email. First, it was considered important to announce, in the subject of the email, the incentive offered and the short time the survey took to be completed. Second, specifically for the outreach practitioners, it was deemed useful to indicate specific advantages the results can offer to outreach at primary level. Final versions of the invitation email are found in Appendix G.

**Introduction of the Survey, Initial question and Biographical questions**

The online survey begins with the purpose statement. Next, it is stated in the survey that participants are free to withdraw at any time and that information received would be dealt in a confidential manner. The teacher version of the survey asked for the participants’ to identify their biological sex, size of school they taught in, and if they had had outreach initiatives before. The outreach practitioners’ version asked for their role in the university, biological sex and how often they carried out outreach initiatives. These biographical questions were adapted specifically for this survey. This adaptation is unlikely to compromise the validity of the validated instrument, as previous adaptations of the survey have also changed biographical questions (Nix et al., 2005).

After the feedback from the interviews, two changes were made in the outreach version of the survey. The initial version only had three roles for research participants to choose from: science outreach practitioner, graduate students, post-docs and research staff. This was changed to clearly express the different roles science outreach practitioners could have: graduate student, outreach officers, post-graduates, lecturers, senior lecturers and professors. The ‘frequency of outreach’ question was also changed. The initial version had the option weekly, monthly, every other month, once a year or other. This was not considered accurate enough, therefore the options were changed to: Every week, less than once a week but more than once a month, once a month, less than once a month but more than once a year, once a year, less than once a year, never did one. The survey continued with the five dimensions of the CLES survey.

**The five components of the survey**

The five components of the survey are personal relevance, uncertainty, critical voice, shared control and student negotiation.

The questions on the teacher version of the survey started with “In my classroom” whilst the questions for outreach practitioners started with “In my outreach initiatives”. The response choices for all items were:

A Almost Always
B Often
C Sometimes
D Seldom
E Almost Never

The four questions for the scale personal relevance were:
In my classroom/outreach initiatives ...
1. Students learn about the world inside and outside of school.
2. New learning relates to experiences or questions about the world inside and outside of school.
3. Students learn how science is a part of their inside- and outside-of-school lives.
4. Students learn interesting things about the world inside and outside of school.
The four questions of the scale uncertainty were:
In my classroom/outreach initiatives ...
5. Students learn that science cannot always provide answers to problems.
6. Students learn that scientific explanations have changed over time.
7. Students learn that science is influenced by people’s cultural values and opinions.
8. Students learn that science is a way to raise questions and seek answers

The four questions of the scale critical voice were:
9. Students feel safe questioning what or how they are being taught.
10. I feel students learn better when they are allowed to question what or how they are being taught.
11. It’s acceptable for students to ask for clarification about activities that are confusing.
12. It’s acceptable for students to express concern about anything that gets in the way of their learning.

The four questions of the scale shared control were:
13. Students help me plan what they are going to learn.
14. Students help me to decide how well they are learning.
15. Students help me to decide which activities work best for them.
16. Students let me know if they need more/less time to complete an activity.

The four questions of the scale student negotiation were:
17. Students talk with other students about how to solve problems.
18. Students explain their ideas to other students.
19. Students ask other students to explain their ideas.
20. Students are asked by others to explain their ideas.

The feedback obtained only suggested an alteration for one dimension. The lack of alterations was expected as the survey validity and reliability had been verified by different studies (Aldridge et al., 2000; Johnson and McClure, 2004). The only question that generated doubts was question 13. During the feedback, the outreach practitioner said that students don’t help to plan future outreach work, as usually they don’t have previous contact with the outreach practitioners. It was decided to eliminate question 13. This does not compromise the validity of the overall research instrument as the five scales have independent high alpha reliability coefficients and are independently analysed (Johnson and McClure, 2004).

5.3.2.5 Implementation of the survey

Obtaining the necessary number of teachers' responses was always a concern in the research design. Primary level teachers and schools have plenty of work and have been targeted for a great number of surveys (Cohen et al, 2007). Therefore, it was decided to roll out the survey first for teachers. To increase the response rate, invitations letters were sent to the 96 schools (Best and Krueger, 2008). First, an invitation letter was sent on the 16th of April, 2013 and a follow up email one week after. The response rate for this survey was very low, not achieving the minimum numbers necessary.

After re-thinking the strategy, phase II of the survey started in September 2013. Another set of 96 schools were selected and two changes were made to the access protocol. The researcher called the schools by phone and explained the survey. Also a new incentive was created: the draw of two Kindles amongst respondents. The second phase of the survey yielded the necessary numbers.
Phase II also included the outreach practitioners. An initial email was sent in September 2013, a follow up one week, two weeks after and a final thank you email. This survey also had the necessary response rate.

After, the next section focus on the sampling procedures.

5.4 Sampling

5.4.1 Sampling for the CLES survey

The Constructivist Learning Environment Survey is used in this study to analyse the perceptions of teachers and outreach practitioners in relation to constructivist learning environments. The research follows a correlational design in which two independent groups are sampled. Correlational designs look at the strength of relationships between the variables (Walsh, 1990). Specifically, in the current study, analysis is carried out to ascertain if there is a correlation between the perceptions of a teacher and outreach practitioner, in relation to their views of constructivist learning environments. This study uses a probability sampling strategy since this is the appropriate method for a correlational design (Onwuegbuzie and Collins, 2007).

The two populations studied are primary level teachers and science outreach practitioners in the Republic of Ireland. For the teachers, the decided sampling strategy was single stage cluster sampling. In a cluster, the members of a population are grouped in such a way that the members of the same cluster are more similar to each other than to those in other clusters (Pallant, 2010). A data set with all of the primary level schools of the country was created and clustered between small and large schools. Small schools are schools with less than 180 pupils (Ó Slatara and Morgan, 2004). Schools were clustered this way because previous research had shown size is a major differentiator between schools in Ireland in respect to their practices (Ó Slatara and Morgan, 2004). Furthermore, the comparison of aspects of teaching between large and small schools is considered very important to assess the viability of small schools (e.g., OECD, 1991; Coolahan, 1994). The formula selected to calculate the numbers of clusters is presented in figure 5.9. The calculations were completed using minitab 10. The final number of clusters corresponds to 96 schools.

![Formula for the sampling design (adapted from Scheaffer et al., 2006)](image)

<table>
<thead>
<tr>
<th>$n$</th>
<th>$N$</th>
<th>$D$</th>
<th>$\sigma_c^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$= \text{number of clusters} - 95.54$</td>
<td>$= \text{total population} - 20,000$</td>
<td>$= 0.0625$</td>
<td>$= \text{average cluster size} - 10$</td>
</tr>
</tbody>
</table>

Outreach practitioners could not be sampled in the same way. As described in Chapter two, outreach relies for the most part, on the volunteer work of graduate students and senior scientists (NeuroScience Editor, 2009). For this reason, there is not a set database that one can obtain and use to sample. Therefore, this study targeted all university staff of science departments, including science outreach officers and post-graduate students, of the five main universities in the Republic of Ireland. This research focused on university-based outreach practitioners because they form a great part of the outreach work carried out in Ireland (Davison, et al., 2008). In order to draw up a contact list of the outreach practitioners, the researcher searched public lists of science departments of the
Irish universities selected, which were available online. The final list contained 423 contacts, which corresponds to the sample population of outreach practitioners for this study.

For a correlation research design, the minimum requirement for participants advised is 82 (Onwuegbuzie and Collins, 2007). In total, the initial population of this study corresponded to 96 schools (768 teachers) and 423 outreach practitioners.

5.4.2. Sampling for the Semi-structured interview

The semi-structured interview designed for this study obtained both quantitative and qualitative information, with an emphasis on the latter. The main objective of the interview was to draw out teachers and outreach practitioners’ perceptions of constructivist science teaching pedagogy. A secondary objective was to compare the positions of teachers and outreach practitioners in relation to the conceptual and pedagogical dilemmas that arise in science teaching and learning. With these objectives in mind non-probability sampling was used.

This stage of the study followed a purposive sampling strategy (Cohen et al., 2007) for each research participant group, teacher and outreach practitioner. The participant pool for the interview aspect of this research was different from that used to complete the survey. When negotiating access to interview revealed a different set of criteria to that of survey access. As such, it was realised that the same participants in many cases were not willing to undertake an additional, extended commitment. A purposive sampling is one that is selected based on the knowledge of a population and the purpose of the study (Palys, 2008). Purposive sampling is biased as it is not randomly picked, and as such does not pretend to represent the wider population (Palys, 2008). To select the outreach practitioners, web searches focused on scientists and science outreach officers that worked with primary level students. Twenty-nine outreach practitioners were contacted for the interview via email. For the teacher population, the objective was to select teachers from large and small schools. Four primary schools in Galway County were selected, two small schools and two large schools. Thirty-one teachers were contacted for the interview.

The number of teachers and science outreach practitioners selected for interview is justified because the qualitative analysis of the interview followed principles from the constant comparative process. According to the guidelines from Onwuegbuzie and Collins (2007), the sample requirement for an analysis of this type is of 20-30 research participants.

5.5 Incentives and ethics

5.5.1 Incentives

Incentives are seen as an important factor in maximizing response rates (Cohen et al., 2007). In the online survey two types of incentive were used. First, a draw was announced for the respondents who completed the survey. The respondents who so desired, included their email at the end of the survey and two Kindles were given away between these respondents. The winners were contacted and the Kindles were awarded in February 2014. Also, a charitable donation was announced for every survey completed. The researcher completed the donation in September 2014.

To obtain teachers for the semi-structured interviews the researcher offered a session of outreach with their students. The researcher completed 30 hours of outreach as an incentive for the interviews. The outreach session was called FrogTV. It built on the footage of a full season of frog development that was recorded in Inagh Valley’s ‘Frogitat’, accompanied by inquiry science activities and projects that linked the existing videos with the Irish primary science curriculum.
5.5.2 Ethics

This research obtained full ethical approval from NUI Galway’s Research Ethics Committee (REC) (Appendix H). This is a university level committee created with the objective to safeguard the health, welfare and rights of human participants in research studies, taking into account the scientific procedures and concerns of the local community (NUIG, 2014). Specific ethical issues of this research are described in this section.

Part of this investigation involved teachers as research participants. Ethical guidelines advise that, when teachers are participants, propositions have to be put to the stakeholders and conditions negotiated (Cohen et al., 2007). To follow these guidelines, access was negotiated through the principals of the primary schools selected.

Primary level teachers’ perceptions in relation to science education were an integral piece of this research. Evidence suggests that science education is considered a challenging subject by primary level teachers (Kim and Tan, 2011; Morrison, 2012). Therefore, teachers might have felt uncomfortable in discussing aspects of science education in the primary sector. Furthermore, teachers may have been concerned that their ability to teach science effectively was being assessed. To remediate this issue, the researcher emphasized to the participating teachers that the interview was about their opinion and perceptions of teaching techniques that are suited to their classroom, not their knowledge of science content or terminology. Moreover, it was assured to the participants that they would be able to read and amend the transcripts to enhance fairness, relevance and accuracy.

Science outreach practitioners’ perceptions and opinions regarding primary level science were also relevant to this research. The practitioners that participated in this study develop science activities with primary level students. Nevertheless, according to Thiry et al., (2008) and Neuroscience Editor (2009) practitioners might feel that they do not have experience/skills to analyse primary level science issues. Consequently, it was stressed to the practitioners that the interview pursued their valuable perceptions on issues related with their science outreach. Furthermore, as the researcher is an outreach practitioner himself he was interviewing people that also developed outreach. The researcher was aware of this fact and monitored his subjectivity (Glesne, 1999). As with the participating teachers, the possibility of requiring amendments was also assured.

Finally, part of the research involved the use of an online survey. The use of this methodology raises particular ethical issues. First, it is difficult to confirm the authenticity of responses of research participants (Cohen et al., 2007). Second, participants might distort their views, in ways they would not do in face-to-face research (Cohen et al., 2007). This is an acknowledged limitation of online surveys. To diminish these issues the link for the survey was only made available through the school principals and research institutes. Moreover, concurrent with the survey, qualitative data was collected through interviews to compare the results.

To assure the confidentiality and anonymity in the interview the names of the participants were changed, assigning pseudonyms in the text. In the online survey, no names were requested and no traceable information was obtained. The exception to this was the research participants who wanted to take part in the draw for the Kindles. They provided their email addresses, although it was agreed that these emails would not be connected with the data collected. Finally, for both research methods, informed consent was obtained. The information sheet and consent form used (Appendix J) followed the guidelines from Heath et al., (2005).
5.6 Data analysis procedures and data quality

5.6.1 Data analysis and Validity and reliability of the CLES survey

The survey data of the participant teachers and outreach practitioners was analysed through Ordinal logistic regression tests. These tests were used to check for significant differences between the variables that characterize the profile of teachers and outreach practitioners. The general linear model was used to compare the responses of teachers and outreach practitioners.

Data quality faces different challenges depending on the data collection procedure being followed. Nevertheless, there are two paramount questions the researcher needs to answer (Teddlie and Tashakkori, 2009). The first one is if the researcher is measuring what is intended. This question relates to the validity of the data. The second question is if the measures are consistent and accurate. This question concerns the reliability of the data. Both questions guided the researcher throughout the investigative process.

The validity of the instrument depends on different subtypes of validity. One of the most important being content validity. To demonstrate content validity, an instrument needs to show that it covers the domain it intends to cover, if it actually measures what it is intended to assess (Cohen et al., 2007). To assure content validity, the researcher selected an approved instrument used in many investigations in formal and informal education environments (Aldridge et al., 2000; Johnson and McClure, 2004; Savasci, 2006). Previous studies have reported CLES content validity in assessing teachers perceptions about constructivist learning environments (Johnson and McClure, 2004).

Convergent validity is also an important factor to determine an instruments’ overall validity. Convergent validity refers to the degree to which measurement outcomes representing a construct agree with the other indicators of the same construct (Teddle and Tashakkori, 2010, p. 210). Convergent validity is indicated by significant factor loadings of each of the measures on the appropriate scale (Walsh, 1990). Convergent validity for the CLES survey has been obtained in previous studies. The factor loadings were calculated for the CLES survey used in this study and loadings of less than 0.30 were eliminated (Johnson and McClure, 2004).

Reliability is defined as consistency and replicability over time and it is concerned with precision and accuracy (Cohen et al., 2007). Reliability can be assessed through internal consistency. Internal consistency represents the degree to which the items that make up a scale measure the same construct (Pallant, 2010). It is measured through the cronbach alpha consistency test. Alpha coefficient values above 0.7 indicate good reliability (Nunnally, 1967). All dimensions of the CLES survey used in this study have yielded alpha coefficient values higher than 0.7 (Johnson and McClure, 2004).

5.6.2 Data analysis and data quality for the semi-structured interview

The qualitative data of the interview was analysed in two ways. First, because the participants positioned themselves in different places within the dilemmas (one extreme or somewhere within the binary), the qualitative data was quantified and the participants were identified along a Likert scale according to the description of their pedagogical choice. The qualitative data from the interviews was analysed according to principles from the constant comparative coding process. The two analysis procedures are now presented starting with the quantitative ones.
5.6.2.1 Quantitative analyses of the interview

Although the interview was qualitative in nature, as the teachers were asked to rate their teaching and learning preference in relation to 6 dichotomies, it was possible to develop a quantitative measurement and translate their rating of each dilemma into data. Three dilemmas were conceptual and explored the dichotomies Autonomy/Dependency, Induction/deduction and Creativity/Guidance. The other three dilemmas were pedagogical and explored the dichotomies Open/Guided Inquiry, Inductive/Deductive Activity and Student /Teacher Led Construction. The three pedagogical dilemmas are derived from the three conceptual dilemmas respectively, as detailed in Chapter 6. The pedagogical dilemmas are, in a sense, a classroom based application of the conceptual dilemmas. Therefore, Open/Guided Inquiry is related with Autonomy/Dependency, Inductive/Deductive Activity with inductive/deductive and student/teacher led construction with Creativity/Guidance.

Some of the teachers and outreach practitioners found it difficult to select one of the options through a fixed alternative response, as initially they were presented with two polar opposite concepts/pedagogies. When starting to reflect on the two views, practitioners would refer to their classroom experience and felt constrained by just two alternate views. Therefore, the initial two point scale was modified to a five point scale to accommodate the practitioners who argued for a mix between the two options, or were inclined towards one option but still agreed slightly with the other one. Teachers and outreach practitioners’ responses were used to define the scales. Figure 5.10 shows the scale defined for the dichotomy Autonomy/Dependency. The scale includes descriptors drawn from teachers’ related responses to each of the five points on the scale. The remaining scales are presented in Appendix J.

Figure 5.10 Five point scale for the dichotomy Autonomy/Dependency

<table>
<thead>
<tr>
<th>Autonomy (1)</th>
<th>More autonomy than dependency (2)</th>
<th>A mix between the two (3)</th>
<th>More dependency than autonomy (4)</th>
<th>Dependency (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The first, I think people should have freedom in the science curriculum. I think in the primary school in Ireland there is the freedom for when you see that something has gained their interest to let them do a project or whatever, so I definitely would go with the first one.</td>
<td>I agree more with the first one that you start from the child’s learning point and their interest, because if they are interested they will do a lot of the learning themselves as opposed to being taught. Of course you do have to give the input from the teacher, input has to be there. We have to make sure that they get a balanced curriculum that they get some from each of the strands and the strand units.</td>
<td>In my class I combine the two. So we’re doing electricity in the class now so I today let them blow up balloons and get the static electricity themselves so they could see actually see how electricity works and then they have to find electricity at home, so I suppose I combine what’s in the curriculum with what they want make it fun and let the children discover like they’re the scientists. I try to combine the two.</td>
<td>At this age group I’d agree more with the second one, more structured. I’ll actually be half way between the two. a grey area between the two, to be honest. I think specially in science there’ll be a lot of don’ts. I think you do have to direct their learning, but, as well just if you could allow them to, say if you do something with water, you could let them play with the water and explore the materials on their own.</td>
<td>Definitely time constrain in here, by the time you get your core subjects, your English, Irish, maths that takes an awful lot of time, and as well, when they go into group learning, giving them time to their own kind of research, at this age, they are very difficult, a lot more work has to be put in to cooperative learning, or working in groups and the ability, the ability of the kids would be a big factor. At this age no, it would be more teacher led.</td>
</tr>
</tbody>
</table>

The responses were coded separately by three researchers. After the initial coding the three researchers consulted with each other to ensure agreement. After this consultation, both intra- and intercoder agreement was above 90%. This is above the range defined by Miles and Huberman (1994). The SPSS 20 software was used for the statistical analysis. The first step included creating the data file in the SPSS 20 and entering the information obtained from each participant for each variable. Next, the data was checked and cleaned for errors. The following step involved obtaining descriptive statistics on the variables of interest, which included the mean, standard deviation, the range of scores, kurtosis and skewness. When the preliminary analysis was concluded, a Mann-
Whitney U test was used to test for differences between teachers and outreach practitioners for the different dichotomies. The quantitative results for the teachers are presented first.

5.6.2. 2. Qualitative analyses of the semi-structured interview

The qualitative data from the interviews was analysed to interpret how primary teachers and science outreach practitioners understand conceptual and pedagogical dilemmas in science teaching and learning. In the interviews, teachers and outreach practitioners engaged in deductive and inductive thinking. Respondents engaged in deductive thinking when they were explicitly presented with opposing perspectives and inductive as they developed their own claims. The coding and sorting of the interview data resulted in key themes that reflect respondents views of the six dilemmas. NVivo software was used throughout the coding process, as detailed in section ... of the previous chapter.

The qualitative analysis of the interview transcripts borrowed principles from the constant comparative coding process. In the process of coding three concepts were used: codes, categories and themes. Green (2008, p. 71) asserts that “novice researchers typically make few distinctions among analysing for themes, categories, and codes”. Therefore, in this study special attention was given to the differentiation between the three concepts. Chenail (2008) describes how the three concepts are used in the analytic process. Coding represents the first step in the analytic process where the researcher attempts to make meaning of the information generated during the interviews. Categories correspond to the second step of the coding process where the researcher looks for connections between or among these separate codes. Finally, the analytic process continues as the researcher looks for patterns that run through and across the system of categories. This leads to the creation of themes, constructs, or domains. These three concepts were used in the analytic process now described.

Boeije (2010) contends that there are four phases in the process of constant comparison. The four phases were applied in this study to obtain an inclusive comparison and interrogation, as reflected in the table 5.1.

Table 5.1 Four phases of comparison (adapted from Boeije (2010, p.84))

<table>
<thead>
<tr>
<th>Analytical stage</th>
<th>Process</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exploration</td>
<td>Discovery of concepts</td>
<td>18 concepts including Connecting theory to practice, context of the student, discover their learning, age dependent, level of the students, their experience as students, students interest, active, explore, experiment, there is no time, cover the curriculum, get the concept, structure, the method, concrete learning, deductive and inductive, experience of outreach</td>
</tr>
<tr>
<td>Specification</td>
<td>Development of concepts</td>
<td>Development of the more recurrent categories including: context of the student, discover their learning, age dependent, level of the students, students interest, explore, experiment, there is no time, cover the curriculum, get the concept, structure, the method, deductive and inductive, experience of outreach</td>
</tr>
<tr>
<td>Reduction</td>
<td>Determining the core concepts</td>
<td>Condensed to four themes Tools to foster students learning Tensions Between the Ideal and the Real, Dynamics of outreach dialectical thinking</td>
</tr>
<tr>
<td>Integration</td>
<td>Integrating the concepts</td>
<td>The relation between the four themes</td>
</tr>
</tbody>
</table>
NVivo 10.2 program was used to carry out this analysis. Sinkovics and Alfoldi (2012, p.5) state that Computer Assisted Qualitative Data Analyses (CAQDAS) such as NVivo create an “auditable ‘footprint’ of the progressive dialogue between the researcher and their data. Furthermore, Veal (2005) suggests that CAQDAS requires researchers to be more explicit and reflective about the process of the analysis.

The analyses was conceptualised in four stages. By using NVivo 10.2, it was possible to interrogate the data, and develop themes from initial codes. This process is now analysed.

5.6.2.1.1 Four stages of the qualitative analysis

Edhlund (2011) suggests a four stage pattern to develop a qualitative analysis in NVivo. This study followed this four stage pattern, as represented in table 5.2. Using this pattern allows one to constantly interrogate the data, moving from codes to higher order themes. According to Edhlund (2011), using NVivo in such a way “helps to organise data so that analysis and conclusions will be safer and easier with the ultimate goal being drawing conclusions” (p. 13). The four stages are now addressed separately.

| Table 5.2. Four stages of qualitative analysis using NVivo 10.2, adapted from Edhlund (2011) |
|-----------------------------------------------|-----------------------------------------------|
| **Analysis stages using NVivo**              | **Processes involved in each stage**           |
| 1. Descriptive                               | Project details                               |
|                                               | Assigning attributes                          |
|                                               | Creating classifications                      |
| 2. Topic                                     | Finding concepts                              |
|                                               | Creating initial nodes                        |
| 3. Analytic                                  | Merging nodes into hierarchies                |
| 4. Conclusions                               | Verification                                  |
|                                               | Drawing conclusions                           |

Stage 1: Descriptive

Stage one involved entering the project details and data into NVivo. This was achieved by entering all of the information relevant to the interview stage of this study. The information imported included interview schedules for teachers and outreach practitioners, descriptive data of the participants, ethical approval letter and consent forms, schedule of times and locations of the interviews, interview recordings, related bibliography, field notes and details of the outreach initiatives. This information was entered in the NVivo sources that include the sub-sections internals, memos and externals and in the NVivo node classifications (Bryman, 2008).

Internals are research materials that are imported or created in NVivo. In the internal section the details of the 61 interviews conducted were incorporated. This included the transcripts and all of the relevant information related to the interviews. In the memo section the research diary was exported from MSWord. The research diary includes ideas and insights related to the project. The node classifications correspond to the attributes of each of the 61 research participants. Attributes are “characteristics or properties of a source item or a node which has or will have an impact when analysing data” (Edhlund, 2011, p.123). Two separate node classifications were created for this study, one for teachers and one for outreach practitioners. The attributes created in NVivo are exemplified in figure 5.11.
Stage 2: Topic, initial coding

Stage 2 started with abstracting obvious topics from the transcripts (Edhlund, 2011). The coding was achieved in two sequential ways. First, the interviews were manually transcribed to MS Word files with the help of the software Potplayer. After, the transcripts were printed and analysed line by line. In the right column the researcher wrote the initial concepts the participants were discussing. Secondly, the initial coding continued with NVivo 10.2. Initial coding in NVivo 10.2 program permitted the grouping of related concepts. In NVivo these related concepts are organized in containers named nodes. These initial nodes are topics, ideas or abstractions that come from the study (Bryman, 2008). The coding in NVivo augmented the manual coding. In NVivo, the nodes are linked to each of the research participants and to each of the dilemmas. This is achieved by creating node classifications. Node classifications were created for the different research participants and for each dichotomy. After the classification, coding in NVivo started. The process of coding began by using the function “right click” to code each of the obvious topics that were appearing. For instance, some coded topics were “you have to give them ways to explore” (interview 52) and “students explore the materials on their own” (Interview 18). In NVivo each coded reference is highlighted and a coding stripe can be assigned, as seen in figure 5.12.
This allowed obtaining a visual image of the coded areas in the transcript. Related concepts in the transcripts were grouped under the same node. It was then possible to open each node to explore the references. By opening a node all of the coded portions of the transcripts under that node are gathered in the same file, as seen in figure 5.13.
The file also signals which transcripts were coded. By clicking that information, it was possible to go back to the original transcript and verify the accuracy of the accounts. At this point, there were 17 initial nodes including: connecting theory to practice, context of the student, discover their learning, age dependent, level of the students, their experience as students, students interest, active, explore, experiment, there is no time, cover the curriculum, get the concept, structure, the method, modelling and concrete learning.

Different methods available in NVivo were used to reflect on the nodes that were developing. First, node files, as the one seen in figure 5.13, allowed analysing the consistency and frequency of the node. Second, framework matrices were created to analyse the codes throughout the different research participants, as seen in figure 5.14. Framework matrices summarize the data in a grid format. The rows represent the research participants and the columns the coded nodes.
Figure 5.14 Example of framework matrix in NVivo 10.2

The framework matrices in NVivo have the advantage of being linked as well to the original transcript. Therefore, by clicking in any of the coded statements, the original transcript appears on the right. Again, this constant referral back to original transcripts was necessary in confirming the codes and developing themes, therefore ensuring confirmability. The analyses of the framework matrices allowed disconfirming some codes, as they did not have enough representability. For instance, some outreach practitioners referred to their experience as students in the interview. Outreach officer Sabrina is an example:

I think the second one is quite an old fashion view. I know that when I was in school we would do an experiment and the answer was given in the title: do an experiment to prove that the boiling point of water is 100 degrees, it's like, ok... so the first one

(Interview 31, Sabrina, Outreach officer)

Nevertheless, as only outreach practitioners referred to this code, it was not developed into a theme. The framework matrices allowed developing the initial nodes. Further analysis was carried out to attain the higher order themes.
Stage 3: Analytic: developing of categories and themes

Stage three corresponded to the initial nodes being merged and re-named into the four main themes: Strategies to foster students learning, tensions between the ideal strategies and the real classroom, the dynamics of outreach, and dialectical thinking. Through axial coding the more relevant codes were selected with the data being sorted into the different themes (Ritchie et al., 2003). For example, the themes ‘there is no time’ and ‘cover the curriculum’ were merged into ‘tensions between the ideal strategies and the real classroom’. This process occurred with the 17 initial concepts that were “refined and relationships among them pursued systematically’ (Benaquisto, 2008, p. 51). As the author reread the transcripts multiple times, the different concepts argued by the participants were integrated in the four main themes. The next section (6.4.3) discusses the four main themes that arose from the data in detail.

Additionally, this organization of themes was continued from the data analysis of both the teachers as well as the science outreach practitioners. Both groups of participants had data in the form of coded responses in each theme. For instance, figure 5.15 shows the frequency chart for participant Jane. In this figure it is visible that teacher Jane made coded references to the four themes.

Figure 5.15 Coded references of Jane for the 4 themes

By clicking on each column of the frequency chart, the participant’s response appeared. Therefore, it was possible to go back to the transcripts to discern and more accurately interpret the meaning each participant spoke of in reference to the themes. Every time the results of the queries gave no coded reference for any of the themes, the transcripts were reanalysed and the coding reviewed. As an example, this was important for the theme ‘strategies to foster students learning’. After rereading the transcripts and recoding it became visible that more teachers spoke of science interest as a strategy to foster students learning, although they used slightly different terminology to suggest this. An example of this is evident in Johanne’s script. She said: “they love these chemical aspects of those kind of explosions and stuff like this, especially younger children love that kind of thing” (transcript 17, Johanne, Teacher for 3 years). Initially, this reference was not coded because Johanne does not speak directly about being interested in science. After rereading the transcript it was visible that Johanne was mentioning strategies that make students interested in the science lesson. Therefore, this reference was coded. Through the use of frequency charts for each of the 61 participants it was possible to tease out the four main
common themes to teachers and outreach practitioners that are presented in Chapter six and that correspond to stage 4.

After describing the qualitative analysis procedures the next section discusses how data quality of the interview was assured.

5.6.3 Data quality of the semi-structured interview

Lincoln and Guba (1985) use the term trustworthiness to refer to the believability of a study’s findings. The authors propose that different criteria should be used in qualitative research, instead of validity and reliability. The criteria defined are credibility, transferability, dependability and confirmability. These four criteria guided the qualitative stage of this research.

Credibility is defined as the procedure which establishes harmony between the participants’ expressions and the researchers’ interpretation of them (Jensen, 2008a). Different techniques are advised to ensure credibility in a study. The techniques include prolonged engagement in the field, triangulation, peer debriefing, negative case analysis and member checking (Cohen et al., 2007). Prolonged engagement is defined as the investment of sufficient time to achieve certain purposes (Lincoln and Guba, 1985, p. 301). The authors argue that it involves spending enough time in a site to build trust, thus giving scope. Persistent observation is needed to establish the relevance of the situation to the research objectives, thus giving depth. In this study, the researcher interviewed 31 teachers from four schools for approximately 20 to 30 minutes each. The interviewer also spent one hour with one class of each teacher doing an outreach session. With the outreach practitioners, apart from the interviews, the researcher spent one hour with 20 of the practitioners doing outreach. Triangulation involves the triangulation of methods, sources, and investigators (Cohen et al., 2007). Methods were triangulated when the data of the interview was compared with the data of the survey. Triangulation of findings was carried out through the quantitative and qualitative analyses of the different types of questions. Triangulation of investigators occurred as three researchers participated in the coding process.

Negative case analysis is the process of finding pieces of data that differ from the researcher’s expectations, assumptions, or working theories (Brodsky, 2008). Negative case analysis was carried out and described in the frequency charts of the different themes identified in the analysis. The last step to assure credibility is member checks. Member checks or respondent validation asks participants in the study to check the investigators representations of events. It is considered the most important strategy for determining the credibility of the researchers’ interpretations (Teddlie and Tashakkori, 2009). Member checks were assured by giving each participant a copy of the interview transcript in order to ensure that their beliefs and ideas were represented accurately accepting changes the participant deemed necessary. Two research participants emailed back changes that were incorporated in the transcripts.

Confirmability is expressed as the degree to which the results of the study are based on the study’s purpose and not altered by the researcher’s bias (Jensen, 2008b). To decrease this concern, the researcher should develop awareness of her/his subjectivity and monitor it (Glesne, 1999). In the current study, the researcher tried to monitor his biases and subjectivity by writing down any biases and beliefs in a research journal.
Biases and beliefs

The main biases the researcher possesses emerge from his previous professional roles, both as a science teacher and science outreach practitioner. As a science teacher, he believes in constructivist teaching and learning and specifically, in developing it through inquiry learning. Nevertheless, he also believes that a perfect method of constructivist science teaching and learning does not exist. To challenge his beliefs and monitor his bias the researcher reads, analyses and discusses research in the educational sciences that challenges constructivist views in the science classroom. For instance, essays that contend that constructivism “does not lead to a prescriptive instructional design theory or to effective pedagogical techniques” (Kirschner et al., 2006, p. 78).

Apart from science teaching, the researcher has carried out science outreach since his third year in university, mostly with primary level students. The researcher has carried out many hours of outreach throughout the years and believes that outreach can evoke a child’s interest in science. Nevertheless, the researcher has always had doubts in relation to the lasting impact of that interest and how significant the outreach was in terms of: was it more than just fun?

These are the two main biases and beliefs of the researcher that could affect this study. He tried to be constantly aware of them to reduce their impact on the research and therefore strengthen the trustworthiness of the research.

5.7. Chapter Summary

The first section of this Chapter provided a justification for the research paradigm followed in this study: dialectical pragmatism. It did this by explaining dominant paradigms in education research and why dialectical pragmatism is the epistemological root of this study. It then discussed why this research employs a triangulation design convergence model. Section two of the chapter described the two research methods employed in this study: a semi-structured interview and the CLES survey. The semi-structured interview follows a novel dialectic method that invites greater engagement with constructivist concepts and pedagogies. The CLES survey is used as a further way to compare the views of primary level teachers and science outreach practitioners. The two methods allow one to examine and compare primary teachers’ and science outreach practitioners’ understanding and perceptions of constructivist science teaching pedagogy. The sampling decisions which guided this research were also described. The ethical issues of this research study and the incentives used to maximize response were discussed. Finally, the validity and reliability of the CLES survey and the semi-structured interview were discussed.
Chapter Six: Analysis of the semi-structured interviews
6.1 Introduction

The aim of this study is to examine and compare primary teachers’ and science outreach practitioners’ understanding and perception of constructivist science teaching pedagogy, in order to improve the hybrid practice of science education/outreach in Ireland. As described in Chapter 5, a semi-structured interview method was developed to examine and compare teachers’ and science outreach practitioners understanding of conceptual and pedagogical dilemmas in science teaching and learning. This Chapter details the results and analysis of the interviews.

The interview designed for this research used a combination of both open and closed ended questions. This type of format generates mixed methods data (Teddlie and Tashakkori, 2009). The interviews were analysed through an inherently mixed data analysis format. This analysis method was used because it was envisioned that the same data source would produce both quantitative and qualitative material (Teddlie and Tashakkori, 2009). More specifically, a fused data analysis was used. It involved the use of qualitative (NVivo 10) and quantitative (SPSS 20) software programs for the analysis of the same data sources in distinct but mutually dependent ways (Teddlie and Tashakkori, 2009).

The rich qualitative data was analysed in two ways. First, because the participants positioned themselves in different places within the dilemmas (one extreme or somewhere within the binary), the qualitative data was quantified and the participants were identified along a Likert scale according to the description of their pedagogical choice. This quantification allowed the presentation and comparison of the practitioners’ choices within each dilemmas. The qualitative analyses allowed going beyond this quantification and understanding the reasoning behind these choices. By presenting the participants with a binary choice, it engaged them in a dialectic reflection. It was this dialectic reflection that allowed exploration beyond the quantitative, ranking data and allowed one to unravel the tensions and contradictions faced by practitioners when having to make choices during their practice (Yoon and Kim, 2009).

The Chapter begins with the discussion of the participant profiles for the semi-structured interviews. A description of the primary level teachers and outreach practitioners is presented. Teachers are described through their years of experience, biological sex, if they have had outreach initiatives in their classroom and if they teach in large or small schools. Outreach practitioners are described according to their biological sex, role, and area of science they do outreach in. Following this, the Chapter continues with the descriptive and inferential statistics results for the two types of research participants. In the descriptive statistics, mean, standard deviation, skewness and kurtosis is analysed. Boxplot graphics are also presented to compare research participants’ responses to the different dilemmas. The quantitative analysis section finishes with a comparison of results between teachers and outreach practitioners.

The qualitative results section presents the key themes discussed in the interviews. The section continues with the description of each theme linking them with the literature analysed in Chapters two, three, and four. Subsequently, the thematic charts for each dilemma are analysed. The final part of this Chapter draws a comparison of the key themes between teachers and outreach practitioners.

6.2 Research participants profile

6.2.1 Teachers
A total of 31 teachers took part in the semi-structured interview. Twenty nine of the teachers were female whilst two were male as illustrated in table 6.1.

Table 6.1 Biological sex of the teachers

<table>
<thead>
<tr>
<th>Biological Sex</th>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>29</td>
<td>94</td>
</tr>
<tr>
<td>Male</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>31</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

From the 31 teachers, nine had less than three years of experience (0-3). Fourteen had three to ten years of experience. Eight teachers have more than 10 years of experience. Table 6.2 reflects this data.

Table 6.2 Years of experience of the teachers

<table>
<thead>
<tr>
<th>Years</th>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 3</td>
<td>9</td>
<td>29</td>
</tr>
<tr>
<td>3 to 10</td>
<td>14</td>
<td>45</td>
</tr>
<tr>
<td>More than 10</td>
<td>8</td>
<td>26</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>31</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Table 6.3 shows the proportion of teachers who taught in large schools, with more than 100 students and the teachers who taught in small schools, with less than 100 students. Eight teachers belonged to small schools and 23 belonged to large schools.

Table 6.3 Size of the schools the teachers taught in

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>26</td>
</tr>
<tr>
<td>Large</td>
<td>74</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

From the 31 teachers, 20 had had science outreach initiatives before in their classroom and 10 had not, as evident in table 6.4

Table 6.4 Outreach initiatives in the classroom

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>68</td>
</tr>
<tr>
<td>No</td>
<td>32</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

The next section of this Chapter describes the profile of the outreach practitioners that took part in the interview.

6.2.2 Outreach practitioners

A total of 30 outreach practitioners participated in the interview. Twelve were male and 18 were female as illustrated in table 6.5.
The outreach practitioners’ role in the university is described in table 6.6. Thirteen were PhD students whilst 17 were post-docs or staff. The post doc/staff group also include lecturers, professors and science outreach officers.

Table 6.6 Role of the science outreach practitioners

<table>
<thead>
<tr>
<th>Role</th>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PhD student</td>
<td>13</td>
<td>43</td>
</tr>
<tr>
<td>Post doc/staff</td>
<td>17</td>
<td>57</td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
<td>100</td>
</tr>
</tbody>
</table>

From the 30 outreach practitioners, 15 performed outreach activities related with biology and six with general science. The remainder were involved in outreach in computer science (3), engineering (2) and physics (3), as illustrated in table 6.7.

Table 6.7 Area of science outreach

<table>
<thead>
<tr>
<th>Role</th>
<th>Frequency</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science</td>
<td>6</td>
<td>20</td>
</tr>
<tr>
<td>Computer science</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Physics</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>Biology</td>
<td>16</td>
<td>53</td>
</tr>
<tr>
<td>Engineering</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
<td>100</td>
</tr>
</tbody>
</table>

The next section of this Chapter analyses the quantitative results of the semi-structured interviews.

6.3 Quantitative results

This section describes the quantitative results obtained through the interview format. The interview sought to examine and compare primary level teachers’ and science outreach practitioners’ understanding of conceptual and pedagogical dilemmas in science teaching and learning.

6.3.1. Teachers

6.3.1.1 Distribution of responses for the different dichotomies

Mean, standard deviation, skewness and kurtois for the six dichotomies are presented in table 6.8. Overall, the mean range was between 2.03 for Inductive/Deductive Activity and 3.17 for
Creativity/Guidance. The range of average item means indicates that teachers argued more for practices that gave more control to the student in the learning process or a mix between the two.

Table 6.8 Descriptive Statistics

<table>
<thead>
<tr>
<th>Dichotomies</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Skewness</th>
<th>Kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>More control</td>
<td>Std. Error</td>
<td>Std. Error</td>
<td>More control</td>
<td>Std. Error</td>
<td>More control</td>
<td>Std. Error</td>
</tr>
<tr>
<td>Autonomous/Dependency</td>
<td>1.0</td>
<td>5.0</td>
<td>2.2</td>
<td>1.3</td>
<td>.68</td>
<td>.42</td>
</tr>
<tr>
<td>Induction/Deduction</td>
<td>1.0</td>
<td>5.0</td>
<td>2.3</td>
<td>1.2</td>
<td>.54</td>
<td>.43</td>
</tr>
<tr>
<td>Creativity/Guidance</td>
<td>1.0</td>
<td>5.00</td>
<td>3.2</td>
<td>1.2</td>
<td>-.10</td>
<td>.427</td>
</tr>
<tr>
<td>Open/Guided Inquiry</td>
<td>1.0</td>
<td>5.0</td>
<td>3.1</td>
<td>1.5</td>
<td>.01</td>
<td>.42</td>
</tr>
<tr>
<td>Inductive/Deductive Activity</td>
<td>1.0</td>
<td>5.0</td>
<td>2.0</td>
<td>1.5</td>
<td>1.04</td>
<td>.43</td>
</tr>
<tr>
<td>Student/Teacher Led Construction</td>
<td>1.0</td>
<td>5.0</td>
<td>2.9</td>
<td>1.5</td>
<td>-.27</td>
<td>.43</td>
</tr>
</tbody>
</table>

From Table 6.8 it is visible that Creativity/Guidance, Open/Guided Inquiry and student/teacher led construction of object were the ones in which the means are less inclined towards the methodologies that give more control to the student. Nevertheless, the mean is not enough to reflect the distribution of responses, especially as the distribution is not normal. It is suggested that in addition to the mean, kurtosis and skewness should be analysed in results with a not normal distribution (Pallant, 2010). A normal distribution has a value of zero for kurtosis and skewness. This is not the case for any of the dichotomies as evident in Table 6.8. The skewness value provides an indication of the symmetry of the distribution. The kurtosis provides information about the peakedness of the distribution (Pallant, 2010). Three of the six dichotomies have a positive skew (Autonomy/Dependency, Induction/Deduction and Inductive/Deductive Activity). This positive skew means that the teachers were more inclined towards the options that gave more control to the student (autonomy, induction and inductive activity). Three dichotomies have a skew close to zero (Creativity/Guidance, Open/Guided Inquiry and student/teacher led construction), which indicates teachers were divided between the two options. Table 6.9 presents a visual representation of this analysis.

Table 6.9 Visual representation of teachers’ preference

<table>
<thead>
<tr>
<th>Dichotomies 1-3</th>
<th>Teacher preference in relation to control of learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a. Autonomy/Dependency</td>
<td>More control to student</td>
</tr>
<tr>
<td>1b. Open/Guided Inquiry</td>
<td>Divided between the two options</td>
</tr>
<tr>
<td>2a. Induction/Deduction</td>
<td>More control to student</td>
</tr>
<tr>
<td>2b. Inductive/Deductive Activity</td>
<td>More control to student</td>
</tr>
<tr>
<td>3a. Creativity/Guidance</td>
<td>Divided between the two options</td>
</tr>
<tr>
<td>3c. Student/Teacher Led Construction</td>
<td>Divided between the two options</td>
</tr>
</tbody>
</table>
The Kurtois values are all negative, meaning that the distribution is relatively flat, with many cases in the extremes. This means that there was a great variability of responses from teachers for the six dichotomies. To make sense of this variability, boxplots are presented to compare the distribution between the related conceptual and pedagogical dichotomies. In a boxplot the length of the box is the variable’s interquartile range and contains 50 per cent of cases. The line across the inside of the box represents the median value. The whiskers protruding from the box go out to the variable’s smallest and largest values. Boxplots provide an indication of the variability of scores (Pallant, 2010). The comparison starts with the first related dichotomies Autonomy/Dependency and Open/Guided Inquiry.

**Autonomy/Dependency and Open/Guided Inquiry**

Figure 6.2 represents the first pair of dichotomies Autonomy/Dependency and Open/Guided Inquiry. The first box illustrates that for the dichotomy Autonomy/Dependency, 75 per cent of the teachers responses were between autonomy and a mix between autonomy and dependency (scored 3 or below). This is not the case for the dichotomy Open/Guided Inquiry. In this dichotomy, 50 per cent of the distribution of the teachers’ responses are between a mixture of Open/Guided Inquiry and guided inquiry (scored 3 or above).

This indicates that a great majority of teachers (75%), when reflecting on the importance of the students having control of their own learning vs teachers taking a more complete role in controlling student learning, teachers agreed more with the former. The results were different when teachers reflected on the pedagogical dichotomy that presented an inquiry activity with two options: one that gave more autonomy to the students and one that gave less, in a practical, investigative class setting. In this case, half of the teachers reasoning fell between a mix of the two approaches and guided inquiry, whilst the other half fell between open and a mix of the two. This indicates that
conceptually most of the teachers argue that students should have more control in their classroom learning in science. Nevertheless, teachers are less inclined to give control to the student when presented with a curricular activity of inquiry. The qualitative results will allow further exploration of the reasons behind the differing teacher views.

**Induction/Deduction and inductive activity/deductive activity**

On the second pair of related dichotomies, Induction/Deduction and Inductive/Deductive Activity, there is little variance between the two, as seen in figure 6.3. For both, 75 per cent of the responses are between induction or inductive activity and the middle of the scale (scored 3 or below), whilst the other 25 per cent are between the middle and deduction or deductive activity (scored 3 or above). The only difference is that, in the dichotomy Inductive/Deductive Activity, 50 per cent of the responses are for inductive activity (extreme option), as indicated by the line that represents the median. This is not the case for the dichotomy Induction/Deduction.

Figure 6.3 Boxplot of teachers’ responses for Induction/Deduction and Inductive/Deductive Activity

This result indicates that, in this pair of dichotomies, a great majority of teachers (75%) argued for the inductive options. This is true both for when the teachers were discussing the concept of induction and also when presented with two specific curricular activities that were based on the two options: inductive activity and deductive activity. Contrary to the previous pair of dichotomies, in this one, most teachers maintained their view across both the conceptual and related pedagogical dichotomy. This result indicates that, in their teaching, teachers argue that learning should move from specific information to a generalization. Students examine facts, data, experimental materials or visual information and form a generalized idea, the related science concept, about them.

**Creativity/Guidance and Student /Teacher Led Construction**
In the final pair of dichotomies Creativity/Guidance and student/teacher led construction, teachers’ responses were distributed more evenly between the options, as seen in figure 6.4. In both boxes, 50 per cent of the teachers’ responses are between one of the extreme options and a mix between the two. Nevertheless, on the dichotomy student/teacher led construction, the teachers who choose open construction chose absolute open construction.

Figure 6.4 Boxplot of teachers’ responses for Creativity/Guidance and Student/Teacher led construction of object

This pair of dichotomies reveals that for both this set of conceptual and related pedagogical dilemmas, when discussing the concept of creativity, and when presented with a related activity, teachers were divided between a more structured approach to problem solving and a focus on the relevance of science theory, rather than leaving space for creative development. Once more the results were consistent for the most part between teachers’ discussion of the concept of creativity (conceptual dichotomy) and how they view a curricular activity that applies that concept (pedagogical dichotomy).

The three pairs of dichotomies

The analysis of the three pairs of dichotomies reveals interesting results. In two pairs of dichotomies: Dichotomy 2 (Induction/Deduction Inductive/Deductive Activity) and Dichotomy 3 (Creativity/Guidance, Student/Teacher led construction) teachers’ views were consistent between the conceptual and the pedagogical dichotomies. It is argued in the literature that sometimes pedagogical choices teachers make in their teaching may not be according with conceptual positions. This is what has been called the dichotomy beliefs/practice, in which teachers beliefs are often not reflected in their practice (Savasci and Berlin, 2012). By presenting both, it was possible to compare teachers’ views of the conceptual dichotomies with the pedagogical ones. As teachers were consistent in both dichotomies this indicates they are certain of their stance.
In the other pair of dichotomies, dichotomy 1 (Autonomy/Dependency and Open/Guided Inquiry), this was not the case. In these dichotomies, teachers argued more for autonomy in the conceptual one, but less in the pedagogical dichotomy. This data indicates that teachers, once having time to apply the theory within a real classroom scenario felt less assured that students should be given autonomy in relation to inquiry learning. This reasoning will be further explored in the qualitative analysis.

Furthermore, the curriculum also argues for creativity. In the case of this interview, both when discussing the concept and when applying it to specific activities, teachers were divided on letting students embark on divergent ideas or having a more structured approach in their teaching. This result indicates the reluctance of teachers’ to give space for divergent thinking, a pre-requisite for creativity (Beghetto, 2007). Finally, as discussed in Chapters two and three, curricular reforms argue for less emphasis on deductive approaches in the science classroom. In the case of these interviews, both when discussing it conceptually or when applying it to a specific activity (pedagogical dichotomy), teachers argued in favour of the inductive approach. Teachers agreed that learning should move from specific information to a generalization, in which students examine facts, data, experimental materials or visual information and form a generalized idea, the related science concept.

The next section analyses science outreach practitioners’ views of the three sets of dichotomies.

### 6.3.2. Science outreach practitioners

#### 6.3.2.1 Distribution of responses for the different dichotomies

Mean, standard deviation, skewness and kurtois for the six dichotomies are presented in Table 6.10. The mean range for outreach practitioners varied between 1.9 for Induction/Deduction to 3.00 for Creativity/Guidance. The range of average item means suggests that outreach practitioners favoured more practices that gave more control to the student or a mix between the two.

<table>
<thead>
<tr>
<th>Category</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Statistic</th>
<th>Std. Error</th>
<th>Statistics</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autonomy/Dependency</td>
<td>1.0</td>
<td>5.0</td>
<td>2.8</td>
<td>1.3</td>
<td>.24</td>
<td>.43</td>
<td>-.81</td>
<td>.85</td>
</tr>
<tr>
<td>Induction/Deduction</td>
<td>1.0</td>
<td>5.0</td>
<td>1.9</td>
<td>1.1</td>
<td>1.11</td>
<td>.43</td>
<td>.49</td>
<td>.85</td>
</tr>
<tr>
<td>Creativity/Guidance</td>
<td>1.0</td>
<td>5.00</td>
<td>3.0</td>
<td>1.2</td>
<td>-.14</td>
<td>.43</td>
<td>-.66</td>
<td>.85</td>
</tr>
<tr>
<td>Open/Guided Inquiry</td>
<td>1.0</td>
<td>5.0</td>
<td>2.4</td>
<td>1.5</td>
<td>.53</td>
<td>.43</td>
<td>-1.2</td>
<td>.85</td>
</tr>
<tr>
<td>inductive/ deductive activity</td>
<td>1.0</td>
<td>5.0</td>
<td>2.2</td>
<td>1.7</td>
<td>.84</td>
<td>.43</td>
<td>-1.0</td>
<td>.85</td>
</tr>
<tr>
<td>student/teacher led construction</td>
<td>1.0</td>
<td>5.0</td>
<td>2.3</td>
<td>1.5</td>
<td>.69</td>
<td>.43</td>
<td>-1.0</td>
<td>.85</td>
</tr>
</tbody>
</table>

Autonomy/Dependency and Creativity/Guidance were the dichotomies in which the means are less inclined towards the methodologies that gave more control to the student, as see in the table 6.10. Nonetheless, the mean is not sufficient to analyse the distribution of responses, more so with a non-normal distribution. Therefore the values of kurtois and skewness are analysed to further explore the data. Four of the six dichotomies have a positive skew (Induction/Deduction, Open/Guided Inquiry, Inductive/Deductive Activity and Student/Teacher led construction of object), implying that the outreach practitioners were more inclined towards the options that gave more
control to the student. The skew value for Autonomy/Dependency is below 0.25, meaning that outreach practitioners were divided between the two options. One of the dichotomies (Creativity/Guidance) has a negative skew, meaning that for this dichotomy outreach practitioners opted for the option that argued for a structured approach in science. Table 6.11 presents a visual representation of this analysis. The Kurtois values are all negative, except for Induction/Deduction. The negative values indicate that the distribution is relatively flat for five of the six dichotomies, with many cases in the extremes. The kurtosis values indicate that there was a great variability of responses from outreach practitioners for five dichotomies. To make sense of this variability, boxplots are presented to compare the distribution between the related conceptual and pedagogical dichotomies. The descriptive analysis starts with the comparison between Autonomy/Dependency and Open/Guided Inquiry.

Table 6.11 Visual representation of outreach practitioners’ preference

<table>
<thead>
<tr>
<th>Dichotomies 1-3</th>
<th>Outreach Practitioner preference in relation to control of learning</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a. Autonomy/Dependency</td>
<td>Divided between the two options</td>
</tr>
<tr>
<td>1b. Open/Guided Inquiry</td>
<td>more control to student</td>
</tr>
<tr>
<td>2a. Induction/Deduction</td>
<td>more control to student</td>
</tr>
<tr>
<td>2b. Inductive/Deductive Activity</td>
<td>more control to student</td>
</tr>
<tr>
<td>3a. Creativity/Guidance</td>
<td>more control to teacher</td>
</tr>
<tr>
<td>3c. Student/Teacher Led Construction</td>
<td>more control to student</td>
</tr>
</tbody>
</table>

**Autonomy/Dependency and Open/Guided Inquiry**

The boxplot presented in figure 6.5 represents the first pair of dichotomies, dichotomy 1 (Autonomy/dependency, Open/Guided Inquiry). For the dichotomy Autonomy/Dependency, 50 per cent of the outreach practitioners’ responses fall between autonomy and a mix between Autonomy/Dependency (scored 3 or below). This is not the case for the dichotomy Open/Guided Inquiry. In this dichotomy, 50 per cent of the outreach practitioners’ responses were between open and more open than guided (scored 2 or below). Twenty five per cent of the outreach practitioners argue for open inquiry (scored 1). Fifty per cent fall between more open than guided and guided (scored between 2 and 5). These results indicate that outreach practitioners, in this interview, were divided between students having control of their own learning within the science lesson and teachers taking a more complete role in controlling student learning, even if it restricts autonomy. The results were different in the pedagogical dichotomy. In the pedagogical dichotomy, outreach practitioners agreed more with the option that gave more autonomy to the student in the inquiry activity. This indicates that while conceptually outreach practitioners are divided between autonomy and dependency, in a specific curricular activity they argue more in favour of the activity that gives more autonomy to the student. When moved from a conceptual to a pedagogical example, outreach practitioners considered the application and the relevance of the classroom context, which generated a different appreciation (Savasci and Berlin, 2012)
Inductive/deductive and Inductive/Deductive Activity

In relation to the second pair of dichotomies, dichotomy 2 (Induction/Deduction, Inductive/Deductive Activity), there is little variance between the two, as seen in figure 6.6. For both, 75 per cent of the responses are between induction or inductive activity and the middle of the scale (scored 3 or below). Nonetheless, in the dichotomy Inductive/Deductive Activity, 50 per cent of the responses are for absolute induction (scored 1). The outreach practitioners were even more inclined towards students learning a concept from experimenting with a concrete example when presented with a specific curricular activity. These results indicate that outreach practitioners in their practice argue that learning should move from specific information to a generalization in which students examine facts, data, experimental materials or visual information and form a generalized idea, the related science concept.
In the last pair of dichotomies, dichotomy 3 (Creativity/Guidance and student/teacher led construction) outreach practitioners’ responses varied more, as seen in figure 6.7. In Creativity/Guidance the responses were evenly distributed (50 per cent between creativity and a mix Creativity/Guidance and 50 per cent between a mix Creativity/Guidance and guidance). In the dichotomy student/teacher led construction of object, 75 per cent of the outreach practitioners chose between student led construction and a mix student led/teacher led construction (scored 3 or below). Twenty five per cent of the outreach practitioners chose student led construction (scored 1). These results indicate that science outreach practitioners, when discussing the concept of creativity, were divided on letting students embark on new ideas and perspectives to promote divergent thinking and increase creativity or having a more structured approach to the solving of problems that increases relevance creativity. This was not the case for the pedagogical dichotomy. When discussing a specific activity, outreach practitioners chose mainly a student led construction of object that encourages students to embark on divergent thinking.
The three pairs of dichotomies

The analyses of the three pairs of dichotomies reveal that just for one of the pair of dichotomies science outreach practitioners’ views were consistent between the conceptual and pedagogical ones. The pair was dichotomy 2 (Induction/Deduction, Inductive/Deductive Activity). When discussing the conceptual and related pedagogical dichotomies outreach practitioners argued mostly for induction. In the other two pairs of dichotomies this was not the case. In dichotomy 1 (Autonomy/Dependency, Open/Guided Inquiry), outreach practitioners views of the conceptual dichotomy were distributed between the two dichotomic poles. In the pedagogical one, outreach practitioners argued more for open inquiry. Similarly, in dichotomy 3 (Creativity/Guidance, student/teacher led construction), outreach practitioners views in the conceptual dichotomy were distributed between the two dichotomic poles. In the pedagogical one, outreach practitioners opted for the option that gave more control to the student in the construction of object.

For the three specific curricular activities (pedagogical dichotomies) science outreach practitioners were guided by what is considered best practice by the reform movements in science education. The outreach practitioners favoured more towards student autonomy in the learning process, be it through open inquiry, inductive activity or student-led construction. Nevertheless, when discussing the conceptual dichotomies, outreach practitioners views were more divided. The contradiction beliefs/practice, in which what participants argue conceptually is different from their pedagogical choices, was visible in the outreach practitioners (Savasci and Berlin, 2012). Outreach practitioners views were divided between giving autonomy to the student and the importance of teaching the whole science curriculum. Outreach practitioners’ views were also divided in terms of letting students embark on new ideas and perspectives to promote divergent thinking and increase creativity or having a more structured approach to the solving of problems that increases relevance.

The next section analyses differences between teachers and science outreach practitioners.

6.3.3. Teachers and Outreach Practitioners
Further statistic tests were conducted to compare the two main groups of this investigation, teachers and outreach practitioners. The tests used were non parametric tests. Non parametric tests were chosen because the population is not normally distributed and the sample size is small. The Mann-Whitney U test was used to test for differences between teachers and outreach practitioners for the different dichotomies. Six Mann-Whitney U tests were carried out to compare teachers and outreach practitioners for each of the six dichotomies (Table 6.12).

<table>
<thead>
<tr>
<th>Mann-Whitney U</th>
<th>Induction/Deduction</th>
<th>Creativity/Guidance</th>
<th>Open/Guided Inquiry</th>
<th>Inductive/Deductive Activity</th>
<th>Student/Teacher led construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>315.0</td>
<td>367.5</td>
<td>404.0</td>
<td>335.5</td>
<td>413.5</td>
<td>340.0</td>
</tr>
<tr>
<td>Wilcoxon W</td>
<td>811.0</td>
<td>802.5</td>
<td>839.0</td>
<td>770.5</td>
<td>878.5</td>
</tr>
<tr>
<td>Z</td>
<td>-2.1</td>
<td>-1.3</td>
<td>-.48</td>
<td>-1.7</td>
<td>-.37</td>
</tr>
<tr>
<td>Asymp. Sig. (2-tailed)</td>
<td>.04</td>
<td>.20</td>
<td>.63</td>
<td>.08</td>
<td>.71</td>
</tr>
</tbody>
</table>

Table 6.12 Mann-Whitney U test comparing the scores of teachers and outreach practitioners for each dichotomy

The analysis of the Mann-Whitney U tests shows that only for the dichotomy Autonomy/Dependency is there a significant difference between teachers (Md=2, n=31) and outreach practitioners (Md=3, n=30), U= 300.0, Z= -2.099 p=.040. The effect size is small r=.002 as defined by Cohen (1998). The teachers of this sample, when analysing the conceptual dichotomy Autonomy/Dependency, were more in favour of students having control of their own learning, whereas the science outreach practitioners divided between the two options. This has implications for teaching and the practice of outreach in the classroom. The Irish curriculum and the science education literature, as discussed in Chapters two and three, argue for students to have more control of their learning in science education. This result indicates that, conceptually, teachers that were interviewed for this study agree more with this view than science outreach practitioners. The next section summarizes the quantitative results.

6.3.4 Summary of quantitative results

The semi-structured interview sought to examine and compare how teachers and science outreach practitioners understand conceptual and pedagogical dilemmas in science teaching and learning. The dilemmas consisted of three conceptual dichotomies (Autonomy/Dependency, Induction/Deduction and Creativity/Guidance) and of three respectively related pedagogical dichotomies (Open/Guided Inquiry, Inductive/Deductive Activity and student/teacher led construction of object). When reflecting on the dichotomies teachers and outreach practitioners argued mostly for concepts and practices that gave more control to the student in the learning process or a mix between the two. The dichotomies in which teachers were more divided between the dichotomic poles were Creativity/Guidance, Open/Guided Inquiry and student/teacher led construction of object. These results reveal that teachers are more divided in their decision to give more or less autonomy to students, when carrying out specific practical inquiry activities. For outreach practitioners the dichotomies in which their views were more divided were Autonomy/Dependency and Creativity/Guidance. These results reveal that both primary level teachers and outreach practitioners views were divided between leaving space for students to embark on new ideas and perspectives to promote divergent thinking and the relevance of a structured approach in the solving of problems.

The results of the analyses of teachers and outreach practitioners responses to the dichotomies revealed some differences between the two groups. Apart from the dichotomy
Creativity/Guidance, the other two dichotomies in which teachers were more divided in their views were pedagogical ones (Open/Guided Inquiry and student/teacher led construction of object). For outreach practitioners the two dichotomies in which responses ranged between the two dichotomic poles were conceptual ones (Autonomy/Dependency and Creativity/Guidance). These results indicate that teachers, when discussing conceptual dilemmas, seem to be more in favour of concepts such as students controlling their own learning than outreach practitioners. On the other hand, outreach practitioners seem to be more open to apply such concepts in specific inquiry activities (pedagogical dilemmas). The Mann-Witney test supports this result as it revealed a significant difference between teachers and outreach practitioners views for the dichotomy Autonomy/Dependency. This was the only dichotomy in which the differences were statistically significant. The Mann-Witney test revealed that, when discussing conceptual dichotomies, teachers argue more for students controlling their own learning in science education than science outreach practitioners.

6.4 Qualitative analysis

The qualitative data from the interviews was analysed to interpret how primary teachers and science outreach practitioners understand conceptual and pedagogical dilemmas in science teaching and learning. In the interviews, teachers and outreach practitioners engaged in deductive and inductive thinking. Respondents engaged in deductive thinking when they were explicitly presented with opposing perspectives and inductive as they developed their own claims. The coding and sorting of the interview data resulted in key themes that reflect respondents' views of the six dilemmas. NVivo software was used throughout the coding process, as detailed in section ... of the previous chapter.

6.4.1 Major themes of the qualitative analysis

There are four sub-sections that present and analyse the qualitative data. The first section, Strategies to Foster Student Learning, examines the various ways the participants articulated perspectives to best promote students learning. The second section, Tensions Between the Ideal and the Real, analyses the relation between the ideal perspectives and the reality of the classroom practice, problematizing the widespread view that teachers do not have constructivist beliefs. The third section reveals an insight into how the research participants view the dynamics of outreach, specifically how they see this relationship working in the classroom. The final section discusses the dialectic reflection of the participants, i.e. how they engaged dialectically in the different dilemmas.

6.4.1.1 Strategies to Foster Student Learning

There is a limited range of pedagogical strategies used in the teaching of science (...) knowledge is seen [by teachers] as a commodity to be transmitted. For instance, teachers will speak of trying to ‘get across’ ideas or that students ‘didn’t get it (Osborne and Dillon, 2008, p.22).

The passage from the report ‘Science education in Europe: critical reflections’ illustrates the common place view that teachers lack diversity of strategies that can foster constructivist learning. Specifically at primary level, several studies have reported the lack of effectiveness of primary level teachers in developing science (Avraamidou, 2013, Kim and Tan, 2011; Ramey-gassert et al., 1996).
The arguments taken up by the participants in the interviews will allow problematizing the *sound bite* that teachers lack pedagogical knowledge to promote constructivist learning (Eivers and Clerkin, 2013; Rocard et al., 2007; Windschitl, 2002). Therefore, this section examines different strategies argued by research participants when discussing dilemmas in science education.

The participants offered different perspectives to the conceptual and pedagogical dilemmas presented. These perspectives illustrate the strategies participants believe can foster students’ learning of science. The perspectives articulated by the participants are therefore divided into five different strategies: science interest, contextualize science with students’ reality, promote exploration, promote haptic learning and promote collaborative learning. These perspectives are now examined, starting with science interest.

In response to the different dilemmas, many participants expressed that students need to be interested for learning to occur. For example, Jennifer, who has three years of experience teaching, stated the following when arguing for students controlling their own learning:

> Well, if they are doing something that they like then they will be more engaged, whereas if they are doing something you would like (...) to get done and you concentrate only on what you want to get done, then they might never learn, they might not remember any of it.

*(Interview 19. Jennifer, Teacher for 3 years)*

Jennifer is recognizing interest as a *kick-start* for learning. She states that without interest they might not learn. In other words Jennifer is arguing that “students must be interested and motivated to learn before learning will take place and this success can lead to motivation to learn more” (Butler 2009, p.1). Beth also connected interest with learning, advocating the importance of interest for students to be motivated to learn.

> I think children retain facts about things they are interested in (...) so just to go this is frog and this is not...let them delve into it a bit (...) because they just naturally crave knowledge about things they want to learn more

*(Interview 5, Beth, Teacher for 7 years)*

John, a PhD student that was completing a module about outreach and was at the time developing an activity for primary level children, argued for students having control of their own learning:

> I think, for me, I would say the first one makes a lot more sense, and I feel that [it] is more forward thinking, it is more modern. The second one seems very restricted, the second one is pointing out how restrictive it can be if you have a too clear curriculum. But I understand the need for it because you need to have everybody roughly at the same level. I go more with the first one because I think you would learn much more if you decide what you want to learn and if you can focus on what you really like and you kind of neglect what you don’t like

*(Interview 41. John, PhD student)*

Interest, for Mary, Jennifer, Beth, John and other teachers and outreach practitioners, was an important factor to motivate students to learn. These teachers and outreach practitioners...
recognized what Krapp and Prenzel (2011, p. 31) affirm: “interest is associated with a pronounced readiness to acquire new domain-specific knowledge”. The role of interest in learning is supported by previous research. Asher and colleagues evaluated the effect of interest in the comprehension of primary level students. The results showed that students’ comprehension was superior on topics they rated as interesting (Asher, 1979; Asher et al., 1978). Further research supported these results as the one by Estes and Vaughan (1973) in which primary level students scored significantly higher in tests when they had classified the topics as interesting versus passages of low interest.

Krapp and Prenzel (2011, p. 31) argue that interest develops from relationships between persons and objects in social and institutional settings. Interest is presented on a continuum between individual and situational. Individual interest evolves through the years and tends to be more resilient and sustaining than situational interest. Situational interest is triggered by the environment and it may or may not have a lasting impact (Hidi and Harackiewicz, 2000). As stated by Logan and Skamp (2013), to achieve better learning and motivation, interest needs to be continued, it needs to evolve from situational to personal interest. Some of the research participants shared this concern by connecting interest with contextualization.

Martha and other research participants associated the role of interest with contextualizing learning with students’ realities. Martha argued: “you should start from what they know and what they want to know” (Interview 6, Martha, teacher for 21 years). Another teacher, Deidre, emphasizes that “the first thing you need to find out from the children is what they know” (Interview 11, Deidre, teacher for 8 years). Patricia, a professor in medicine and developer of outreach programs also argues for contextualization when discussing the flower power activity: “she needed to put it into context for the children, why do they care about how plants use water?” (Interview 30, Patricia, Professor).

Martha, Deidre, Patricia and other participants’ views go to the heart of reforms in science education as stated by the National Research Council:

Inquiry into authentic questions generated from student experiences is the central strategy for teaching science'

(National Research Council, 1996, p. 32-33)

Furthermore, they realize that interest and motivation is more likely achieved if the learning starts from children’s knowledge and experience. As the science outreach officer Steven states: “I think it is better to contextualize on things that happen with the students first and giving them something they can relate to” (Interview 35, Steven, science outreach officer). This view is recognized by Raizen and Michelsohn (1994) as the one that embodies characteristics of effective primary level science teachers. For these authors, effective primary level teachers are aware of children’s ideas, prior knowledge and experience. Contextualizing learning with students’ realities is as well in accordance with the methodology of inquiry learning that argues that making science real is a key aspect for science motivation. As put by Butler (2009, p. 1):

Young children’s daily realities are fertile ground for helping them observe and understand the world around them. Students’ “funds of knowledge” (i.e., the information and experiences they bring with them to school) can be tapped to encourage and engage them in the science they need to know and be able to do.

As such, teachers and outreach practitioners recognized student interest and contextualizing with students realities as two of the tools to foster students learning. This view is aligned with proponents coming from education psychology that argue that science teaching in primary level
must be guided by student interest, motivation and what they already know (Tobin and Tippins, 1993).

The fact that research participants recognize two key strategies, argued by the literature to guide science teaching, challenges the common place view that teachers lack pedagogical knowledge to effectively carry out science teaching aligned with the movement reform. These were not the only strategies participants argued for. When discussing the dilemmas other methods were prevalent.

Starting from the context of the students and connecting with their interests was just part of the toolkit that teachers and outreach practitioners mentioned to foster students learning. For instance, Mary discusses how she would conduct the science activity build and play with a magnetic car

The best, I think that for younger children, the first one and [for] the older ones, the second one. To be honest the first one [observation], she told them everything and showed them everything and I wouldn’t agree with showing and telling them everything, I think it’s better to just, maybe she didn’t need to say: if you put the two, you know, the north and north together it is going to repel. You don’t need to tell them that all first, maybe explain after and let them come up with the science, because some of the clever kids of the class will be able to tell you because they know from magnets from home so, I wouldn’t agree with telling them everything, I think it ruins the science in a way

(Interview 58, Mary, Teacher for 10 years)

Mary compared the opposite views of conducting the activity. Initially, she agrees with the observation approach for younger students. Nevertheless, after reflecting, Mary changes her view and synthesises a new way of doing the activity. She does not agree with explaining the concept first. Only after the students had the chance of exploring would she explain the concept. Moreover, Mary emphasizes that students will know magnets from home, therefore the science is contextualized with the students’ reality (Butler, 2009). And as the science is contextualized she wants them to explore, “to let them come up with science”. Furthermore, she argues that explaining it first, may ruin the science and as such the act of personal inquiry.

The view Mary argues for is clearly aligned with a constructivist inquiry based philosophy. Mary believes that a confirmation experience, in which students verify a principle already taught to them (Windschitl, 2003) ruins the science. If the students are given an explanation about the magnets first, the experiment becomes just a confirmation one. Mary argues for a guided inquiry approach, where the problem investigated is known, but “the methods to resolve the problem are left open to the student” (Windschitl, 2003, p. 115). The way Mary structures the activity is congruent with the role Gil-Pérez et al., (2002) argues for students in the learning process:

A constructivist approach in science education is a proposal that contemplates active participation of students in the construction of knowledge and not the simple personal reconstruction of previously elaborated knowledge, provided by the teacher or by the textbook

(Gil-Pérez et al., 2002, p.561).

Other teachers and outreach practitioners also believe in the role of exploration to promote students learning. For instance, Flora, argues
In this school, everything is done in groups and exploring first, before you teach a lesson. They learn more by exploring themselves, figuring things out by themselves and getting their own ideas. Yes, because it gets them thinking as well, do for themselves and actually figuring out how they should experiment themselves

(Interview 22, Flora. Teacher for 8 years)

More than in science, Flora is emphasizing the role exploring has in the whole school. It emphasizes a view of teaching argued by the pedagogue Koch (2002) in which the students must engage in explorations and furthermore, reflect on them and develop new ideas (p.114). Mary and Flora’s reasoning challenges the views that teachers have naïve notions of exploration in science. These views are common in the education literature. For instance, Faikhamta (2013) criticizes teachers’ view of the nature of science as a discovery approach since they hold naïve views of science. As well, Davis et al., (2006) argues that teachers hold the common view that inquiry is synonymous to hands-on activities completely student-directed with very little input from the teacher, making it difficult to adopt an inquiry based philosophy. Biggers and Forbes (2012) name this a discovery view of inquiry in which there is little space for analysis and interpretation.

Nevertheless, as the reflection on the dilemmas reveals, Mary, Flora and other teachers and outreach practitioners emphasise a process that goes beyond exploration. As both quotes show, the teachers refer to thinking and reflecting, not only the ‘hands on process’. Second, both mention the role of the teacher. Flora mentions that after the students’ exploration, the teacher will consolidate the learning (“the teacher teaches the lesson”). Similarly, Mary states that teacher explanations come after the students come “up with the science”. Julia, an outreach officer, also emphasizes the role of higher order thinking skills such as analysis and interpretation.

Certainly at the primary level that process of reflection and inquiry is, I think, fundamental, fundamental skills for people to learn. As fundamental as whatever the information is. So, there has to be time given for reflection and inquiry and perhaps some sort of independent inquiry and learning.

(Interview 59, Julia, Outreach officer)

This view of exploration goes beyond the naïve or discovery view of which inquiry teachers are accused (Davis et al., 2006; Biggers and Forbes, 2012). Several of the participants in the dilemmas argued that in their practice they value students’ exploration but accompanied by the process of reflection and with the scaffolding of the teacher. This is how these practitioners view exploration as a tool to foster students learning and not only the hands on approach. Nonetheless, the respondents acknowledged the role of hands-on approaches in the learning of science.

Many of the participants reflected not only on the role of exploration, but more specifically on the importance of touching and engaging with actual materials, in science.

everything that has concepts to do with it has to come from your own concrete hand on activities or their own kind of understanding, they just..., they need direct experience before, and then they have an amazing ability to retain facts as well but I think, it’s good for them to have that direct..., it’s all about gaining their interest as well, you know what I mean, they have to touch things themselves. They have to have their own direct contact.

(Interview 5, Beth, Teacher for 7 years)
Here Beth reveals an elaborated view of what for her, it means to use hands on learning in promoting her students learning and interest in science. What Beth and other participants refer as “hands on activities are essentially haptic experiences that prompt students to explore and manipulate objects and materials” (Jones et al., 2006, p.111). What distinguishes the haptic exploration is its kinaesthetic and tactile nature (Paivio, 1986). The tactile and kinaesthetic nature was visible in other participants’ responses. For instance, Tania, a post-doc researcher that develops outreach with primary level students, argues for an inductive way of presenting the magnets activity:

Magnets, you can get to the final conclusion, because it is very practical and you, just by forces, you understand what it means. This is maybe an example that I could, you could try to even at a young age, to let them do the full thing and not guide them through. And because, it is more hands on, it is more practical, it is more, how would you say, the flower is also visual, so you can also arrive to a conclusion, but, it gives that feeling

(Interview 56, Tania, Post-doc researcher)

Tania argues that they should carry out the activity before the concept is explained to them. She even compares it with the flower activity and argues that, although the flower is also visual, with the magnets it is more than that, they can experience it physically. She sees an opportunity for a kinaesthetic and tactile exploration in this activity. Also Molly, another post-doc researcher with several years of experience in developing outreach for primary level children sees the value in haptic learning:

The children are allowed to play and to touch and feel, to experience something. I think it probably stays in their brain a lot more, the more interactive something is. I guess rote learning hasn’t been shown to be particularly effective

(Interview 64, Molly, Post-doc researcher)

In Molly’s analysis, she too draws connections between the importance of touching and feeling, of the kinaesthetic exploration and learning. This connection has been discussed in the science education literature where it is argued that the active manipulation of objects is a more efficient way for students to meaningfully learn science than employing more deductive ways (Glasson, 1989; Vesilind and Jones, 1996). Nevertheless, how tactile experiences contribute to the learning of science is still being researched. Dual coding theory is one of the fields that offer an explanation for this contribution. Dual coding theory sustains that students encode information through verbal and nonverbal channels. As such, tactile experiences are encoded as images instead of verbal information. According to cognitive load theory (Chandler and Sweller’s, 1991; Sweller, 1999) these channels in the human information-processing system have limited capacity. Therefore, if multiple channels are used by students the cognitive load can be reduced (Mousavi et al., 1995), which increases students interest (Sathian, 1998) and more learning can happen (Jones et al., 2006). More participants argued about the importance of touch and feel and learning. For instance, Charlie argued the following:

[The] more hands on activities for the children, the more interested they are going to be, especially for the little ones, rather than me telling. So you know the more involvement they have, those kind of concrete activities, and they are, it is amazing what they can find themselves

(Interview 48, Charlie, Teacher for 3 years)
Again, there is the belief that kinaesthetic and concrete exploration can improve the learning and interest in science.

Finally, some of the participants argued that exploration and learning of science is more fruitful if children are working together, collaboratively. These respondents offered another strategy they believe can foster students learning. Lucy’s response to how she can promote learning in big classes emphasizes the idea of a community of learners.

the class is quite big, I find that pairing them with a child more able, like able to guide them, so their learning from each other and, it’s impossible, you couldn’t sit beside one child and then teach the rest of the class, you have to, kind of maybe, pair them with someone and they’ll work together, group work

(Interview 23. Lucy, Teacher for 1 year)

Lucy believes in the sociocultural nature of learning that “suggests that work with other individuals is a critical component of the process of knowledge construction” (Koch, 2006, p. 107). For Lucy, learning in the classroom for all the students is only possible if they collaborate with each other, pairing the more with the less able, working in what Vygotsky theory of sociocultural constructivist learning defines as zone of proximal development.

The distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance, or in collaboration with more capable peers.

(Vygotsky, 1980, p131).

Lucy recognizes the potential benefit in learning for students, when presented with activities in which they collaborate with more capable peers. The upper limit of the zone of proximal development is not achievable without social interactive support from peers and teachers (Vygotsky, 1980). Collaborative leaning is also raised by Chloe when she explains that:

They [the students] are better when they are working in groups, instead of you talking the whole time because they get bored immediately with that, they have a short attention span, its better when they work together, its better having them [in] control of their own learning, start from where they are at

(Interview 10. Chloe, Teacher for 2 years)

Chloe’s statement alludes not only to why collaborative learning is important, but also to the relevance of students being interested when she argues that they will be bored with lecture type teaching. Furthermore, she also associates collaborative learning with giving students control.

Johnson and Johnson (1986) claim that there is convincing evidence that cooperative communities of learners are more interested, achieve higher levels of thinking, and can memorise and apply their learning better than individual learning scenarios. Furthermore, Totten et al. (1991) argue that working cooperatively allows students to control their learning and become critical thinkers. In recalling the outreach workshops she developed, PhD student Elisa noted the following regarding the wag the dog activity:
Even if it doesn’t work, they will get it because they will see other peoples’ [activity] having worked and obviously they will want theirs to work and they will want to know why it didn’t work. You will learn as much from not doing things or doing things the wrong [way], they will really get it then if it doesn’t function because they will want theirs to work as everyone else’s

(Interview 43. Elisa, PhD student)

Elisa believes that working in groups will allow students to reflect on their work by comparing it with the work of others. For Elisa, in such a community of learners, errors are seen as an opportunity to really get it, to obtain meaningful learning. As put by Koch (2002,p.101), “in a community of learners model learners in search of understanding communicate with others and formulate and reformulate their thoughts based on peer and expert feedback”.

The different arguments taken up by the participants indicate that many of them possess expert knowledge and recognize relevant Strategies to Foster Student Learning. This indicates a disconnection between what is found in the literature and what these participants are arguing. For instance, Thomson and Gregory (2013) maintain that most teachers hold traditional or transitional beliefs lacking pedagogical knowledge and mainly teach science in a deductive, teacher-centred way. Windschitl (2002) also argues that teachers fail in developing more student-centred teaching and learning in their classrooms due to a lack of conceptual and pedagogical knowledge of constructivism. But, several of the teachers that participated in this study revealed an abundance of pedagogical knowledge in particular in relation to a constructivist approach to learning, reflected in their discussion of a variety of strategies that they use or advocate to foster student learning. Furthermore, they explicitly recognize that this knowledge comes from their initial teacher education. Chloe states that she knows that it is important to contextualize learning with students’ realities and having them work collaboratively because this is what she learnt in college.

Because I was told in college to start off from where they are, because they’re better, you know, when they’re working in groups and all of that.

(Interview 10. Chloe, Teacher for 2 years)

Ruth also argues for students exploring their own learning because that is what she remembers from her teaching classes:

you want them to come up with their own learning, because I know from teaching classes, that if you give them too much, if you taught them too much then they just zone out, you know, in the teaching training colleges they do encourage you to let the children talk more than the teacher

(Interview 9. Ruth, Teacher for 4 years)

Other participants also acknowledged that their pedagogical knowledge comes from what they have learnt in the teacher training colleges or in professional development workshops. Nevertheless, several reports that analyse teaching in Irish primary classrooms argue that teaching is still “predominantly characterised by whole-class teaching and by pupils working by themselves (rather than in pairs or in small groups)” (Eivers and Clerkin, 2013, p. 78), There is a clear mismatch between what the participants are arguing for and what is reported. The next section analyses reasons put forward by the participants that can explain this mismatch.
6.4.1.2 Tensions between the ideal strategies and the real classroom

Looking at that I would say the first one, but, I’m in the class, it’s different, it could get chaotic; you don’t have that much time, so you just tell them what to do next. But I would agree with the first one that they would figure it out. [...] I am with 20/30 kids depending on the class size, so that’s the problem. In an ideal world, the first. [...] I would need more helpers in the classroom

(Interview 3, Anna, Teacher for 7 years)

Anna argued this way when discussing the importance of students having control of their own learning in an inquiry activity (flower power activity). This quote starts revealing why, in their practice, teachers often do not apply constructivist practices, in spite of having expert pedagogical knowledge of different strategies. Earlier in the interview, Anna chose autonomy and argued for the importance of students exploring as part of their learning. When faced with the pedagogical dilemma, she reflects on both dialectical poles. Anna even recognizes that open inquiry is the one that would facilitate exploration: “that they would figure it out”. Nevertheless, when analysing the dilemma, she related it to her practice. Anna reflected about her students, about her context, and she couldn’t see it working there. Anna teaches junior students and she believes open inquiry would take too much time: it would be chaos. Therefore, she has to guide them. Anna is clearly identifying a tension between what she wants to develop with her students (the ideal exploration in an ideal world) and the problems she sees that ideal bringing (too much time, chaotic). When asked what she would need for the ideal world to happen, she negotiated the dialectic: “more helpers in the classroom”. Anna believed that, due to the time which open inquiry takes, she would need helpers to facilitate it effectively. In Ireland, teaching assistants are mainly present to assist with students with special educational needs (Travers et al., 2010); science teaching assistants are not common.

Teachers’ perceptions such as the one Anna verbalised are sometimes classified in the literature as transitional constructivist beliefs: “Classroom practices for this group of teachers are also beginning to align with reform, but the teacher still exhibits some traditional beliefs and/or practices” (Levitt, 2002, p.8). Through the dilemmatic reflection, it is possible to problematize this classification. Anna’s reflection indicates that she does not hold transitional constructivist beliefs. Even when analysing a pedagogical approach she recognizes that the one that gives more control to the student is the best. Nevertheless, Anna sees the tensions and problems she will face in her classroom if she were to apply the open inquiry practice. Therefore, she chooses the guided inquiry. As such, she is not being ‘traditional’ as the literature suggests, she is being realistic about the demands of the classroom.

Anna was not the only teacher mentioning tensions related to the demands of the classroom. Padraig, a primary level teacher for six years, explained why you need a balance between autonomy and dependency:

I think, well, from that you need a balance between the two, because there is a strict curriculum that you have to do which is set in front of you, and teachers seem to concentrate more on just getting every topic covered as opposed to concentrate on what the kids are picking up, and then I know some parts of it would interest the kids more.

(Interview 49, Padraig, Teacher for 6 years)

In making this comment, Padraig argues that the amount of topics in the science curriculum impairs teachers from further developing topics that interest children. Again, it is
visible that Padraig compared both dialectical poles in the dilemma. He acknowledges and agrees that if the student has more control in the learning process, the interest levels will be higher. At the same time, Padraig feels constrained by the curriculum. Therefore, his solution for this dilemma is to balance the two views. Padraig mentions the issue of time in connection to the curriculum. He believes that there is a strict curriculum. It is this strict curriculum that impairs the teacher in terms of developing approaches that give more control to the students. This view is interesting because the curricular document itself seems to contradict this view. In the teacher guidelines of the Primary curriculum it states:

> It is not expected that children would cover each objective within each strand unit. The strands provide a menu from which teachers and schools can select topics that best reflect the aims and objectives of the curriculum and that enable the pupils to apply and develop their scientific skills and understandings in a broad range of contexts [...]. The methods the teacher employs to manage the science lesson will depend on the number of children in the class, the resources available, the space available, the activities that are planned and the teacher’s own methodological preferences (DES, 1999, p. 7, p. 52).

This quote exemplifies that the curriculum gives freedom to the teacher. It states that teachers should develop teaching approaches that are best suited for their class, for the different activities and even according to her/his preference. Moreover, it is also mentioned that teachers should not cover every objective within each strand. Therefore, the curriculum gives different options for teachers to develop the curriculum as best suits their students. Nevertheless, teacher Padraig still argued that the curriculum is strict. The research carried out by Orpwood (1998) offers an explanation as to why Padraig may think this way. According to Orpwood (1998), teachers tend to ground their teaching in the sections of the curriculum that specify content and not as much on the guidelines. The curricular document that specifies content does not mention that not all of the objectives should be taught. It only states the contents and skills for each theme. Therefore, teachers might feel this document is quite strict as: “teachers seem to concentrate more on just getting every topic covered” as teacher Padraig himself mentioned.

Moreover, in terms of content, the Irish curriculum has many more curricular statements than other curricula, such as, e.g., the Finnish curriculum for primary level science. Just for the 5th and 6th years the Irish document has 70 curricular statements whilst the Finnish has 20 (DES, 1999; Finnish National Board of Education, 2011). This leaves Irish primary level teachers being presented with a large amount of content that they feel they need to cover. The issue of curriculum has been acknowledged in other studies. For instance, in the study of Haney and McArthur (2002) with prospective science teachers, it was concluded that: “each teacher was unable to operationalize the peripheral belief of shared control [...]. The belief in the need to adhere to the existing local science curriculum was an evident obstacle (conflict core belief) for all four teachers” (p. 797/798). Again, the dialectical engagement with the interviews problematizes the view of teachers having peripheral constructivist beliefs. For instance, Padraig, who argued for the balance between autonomy/dependency due to curricular constraints, analysed the dilemma open/guided inquiry (flower power activity) in the following way:

> I think that it is definitely the best way [open inquiry]. Because they come up in groups with some different ways and then you know there would be more ways of talking about it then and they’ll see, there are probably different outcomes as
well, and they’ll see what was the right way, from doing it themselves as opposed to be just given and said do it like that. I think they should definitely be allowed to do it that way [open inquiry]. And then you know they come with their ideas and then at the end they come back and have a look at it and they’ll see, well that’s the right way and then they can write their report. You see, whenever we’re doing an experiment or whatever they always have a conclusion you know, and what we could have done, what we did wrong, I think that would be the best approach.

(Interview 49, Padraig, teacher for 6 years)

This quote reveals that Padraig strongly believes in developing the inquiry activity in the way that gives more control to the students. In spite of recognizing tensions of time and curriculum, he still argues for open inquiry. Again, it seems more a question of negotiating the tension between the beliefs the teacher has and the constraints he recognizes, more so than Padraig not having core constructivist beliefs.

One of the main advantages claimed for science outreach is that it does not suffer from the constraints of formal education, such as curriculum. As Padraig and other participant teachers’ revealed, they feel they need to teach all the strands presented in the Irish curriculum and this impairs more open ended experiments. Science outreach activities do not follow a science curriculum. Therefore, it is assumed that time constraints are less of an issue (Digas et al., 2007) Nevertheless, some outreach practitioners acknowledged these constraints. They used time constraints when discussing different dichotomies. John, a physics PhD student that is doing a module about outreach, raised his concerns in relation to open inquiry:

I have to say, again, that here a mixed approach would probably be best, because video number 4a (example of open inquiry) makes a lot of sense but in my opinion, might use too much time and people might go in to too many different directions. [...] I would be afraid that you would have kids going in the wrong direction and keep doing this for an hour.

(Interview 41. John, PhD student)

In other words, John believes that it would be too time consuming to allow children to perform an open ended experiment. Contrary to Padraig, John was more concerned in having the students doing the experiment in a certain time frame, than seeing the different directions as an opportunity for learning. Molly, a Biology post-doctoral researcher that develops outreach programs, also raised time concerns in the Inductive/Deductive Activity dichotomy:

what I liked about the first one was that there was a really good explanation about magnetism and effects of magnetism [...] Making the car I think that is quite hard, and probably end up messing about spending a lot of time making the car and you need to get everything done in a certain time frame.

(Interview 64, Molly, post-doc researcher)

Again, Molly is saying that the key constraint in carrying out the activity in this way is time. She argues that there is a need to get everything done. Therefore, the issue of time needs to be a consideration, when choosing the type of activity you bring to the classroom. Similarly to the participant teachers, Molly, John and other outreach practitioners reveal a tension between the ideal pedagogy, the ideal strategies, and the reality of carrying out the outreach activity in a given time frame, the reality of the classroom.
What the two quotes from outreach practitioners also reveal is that they mention time in the context of an activity. Outreach practitioners are concerned about getting the activities completed in a certain time frame. They did not refer, in general, to issues of curriculum and how time is an issue in the context of the Irish primary level curriculum. This might be explained because outreach initiatives consist predominantly of activities that are brought to the school. These activities are usually carried out in replacement of the weekly hour that is allocated to science in those schools. Therefore, outreach practitioners might feel constrained by developing the outreach initiative within the limited time they have allocated to them.

Many participants, when discussing science activities, rationalised their choices of giving less control to the student due to tensions of time and curriculum. Many of the participants recognised the impracticality of an open-ended approach because both groups argued that time did not permit the ideal approach. This analysis shows that the lack of constructivist practice evident in the classroom cannot be explained by the lack of conceptual and pedagogical knowledge of constructivist practice. The engagement and arguments used in the different dilemmas challenges some of the assumptions that are made of teachers.

In the literature, teachers are usually classified into three distinct categories regarding constructivist practice. Two are the extreme categories, traditional and transformational. Traditional teachers are the ones that are more at odds with the recommendations of science education reform. Transitional teachers are the ones whose beliefs and practices demonstrate the closest alignment with constructivist pedagogy. As previously stated, teachers classified as having transformational beliefs demonstrate practices that begin to align with reform, but the teacher still has some traditional characteristics (Levitt, 2002).

When analysing the participants’ argument in relation to the dilemmas presented to them, this framework revealed to be too rigid in terms of aligning with the complexity of responses given. The different strategies which participants described to foster students learning show that many hold knowledge and beliefs coherent with movements of educational reform. Moreover, the different dilemmas allowed the understanding that, when participants move from discussing concepts of constructivism and go into the discussion of real classroom scenario’s, that it becomes more complex. Time and curriculum issues arise and teachers acknowledge that problems exist. They cannot see more open ended approaches working with classes of 20/30 students. Many argue for the impracticality of open ended activities when they have a large curriculum they feel they need to cover. Furthermore, this curriculum needs to be developed in the weekly hour that is allocated to science. An hour that represents only 5% of the teaching hours for all subjects.

Several of the participant outreach practitioners recognize that it is difficult to develop activities that give more control to the student in a limited amount of time. Therefore, and contrary to the common place views (Abell and Roth, 1992; Appleton, 1995), this analysis suggests the problem is not the teacher and their lack of pedagogical knowledge. Many of the participant teachers revealed they have this pedagogical knowledge. The resistance to the ideal model comes from practical constraints. And even outreach practitioners, that are challenged to bring more open ended inquiry activities, recognize similar practical limitations.

The practical issues raised by the participants extended beyond time and curriculum. Several participants argued that more open inquiry activities might not work for all students. These participants raised issues in relation to the level of the students. For instance, Florence analysed the two options for the flower power activity (Open/Guided Inquiry) in this way:

I suppose in older classes you could give them all the apparatus and say: off you go!; but in junior classes you’d probably do it in smaller groups and you’d probably go around their group and then you would focus the group and then guide them in the right direction. I don’t think I’d do that in a whole class set anyway with
children going and then off you go, I don’t think that would work. (...) I think it really depends on the class level, like it’s easy to give you know, you can tell the children what to do but I think they learn when they do it themselves, it kind of sticks, I don’t know.

(Interview 15, Florence, Teacher for six years)

In making this comment, Florence argues that younger children need a more guided approach whilst the older students can be given more autonomy in an inquiry activity. She clearly identifies the open-ended approach as the best one. Nevertheless, she knows, from her practice, that it wouldn’t work with younger primary level children. In the activity build and play with a magnetic car, Florence has a different view:

The second one straight way, she shows them how to make the car which is fine, but then she allows them. In the first one she tells them everything, how magnets work, but in the second one they discover how. I think that’s a definite where you could allow the children to find it out themselves.

(Interview 15, Florence, Teacher for six years)

In this activity, contrary to the Open/Guided Inquiry, Florence believes they can have control of their own learning. It is an activity in which she feels confident that it would work even with her young students. Florence wasn’t the only one who held this view. Many participants argued that younger students needed more guidance in the flower power activity than in the magnets one. As in the second activity (magnets), students only need to play with the cars to understand the concept, the participants see it working. Barbara says the following regarding the same activity:

I like the second way (inductive activity). I think it’s very easy to understand as well what you have to do, first you just have to make the magnet box, the car and then they discover for themselves what makes the car move”

(Interview 25, Barbara, Teacher for eight years)

Similarly to Florence, Barbara can see that children would be able to discover for themselves in this activity. She believes they will be able to explore on their own the concept of the magnet by playing with the car. For the inquiry activity, Barbara reasons differently:

Well, the first one would be very difficult for this class [open inquiry]. They wouldn’t have a clue what was asked of them, they wouldn’t know where to start, what exactly they were learning. So definitely for this class, I would use the second way. The learning objective was there straight away, the question that they have to follow, gave them more structure. But yes, let them do the experiment and figure it out for themselves, I would prefer that way, maybe for secondary school might be the way forward

(Interview 25, Barbara, Teacher for eight years)

Again, as with Florence and other participants, Barbara cannot see an open inquiry activity working for this class. This is not because the participants do not hold constructivist views. Both argue it would be the best way for older classes and both chose an open activity when it comes to the magnets. What the participants are arguing is that a scientific inquiry activity with primary level
children needs more structure. The educational literature itself recognizes issues of teaching science to young students:

No one really knows the best way to teach science to young children. Similarly, little is known about how to support preservice early childhood teachers crossing the borders between the science education community and the early childhood education community. What is known is that the research base in science education has concentrated on children aged 8 years and older. Also, this research has been used to inform the development of teaching approaches in science education. As such, more thought should be given before applying a deficit model to early childhood science education (Fleer, 2006, p. 121)

As Fleer highlights, primary level teachers are being asked by curricular reforms and by many science education reports (DES, 1999; European Commission, 2007) to develop science using teaching approaches that have been advanced and researched for older students. Furthermore, teachers are then accused of not having content knowledge, confidence and of holding negative attitudes towards science:

A review of the literature [...] indicates various related problematic issues with elementary teachers. Such issues include the lack of content knowledge, lack of confidence in teaching science, and negative attitudes toward science (Avraamidou, 2013, p.1703)

Further, due to these perceived issues, outreach officers are tasked to bring more open ended pedagogies to the classroom. But experienced outreach officers also perceive practical issues. Jane, an outreach officer with more than ten years of experience argues, regarding the flower power activity:

“I think it depends on the age of the children and I think it depends on the background of what they have been learning. So, I’m talking now as an outreach officer, not as a teacher, of course I don’t have that experience, but when I went to some classrooms I tried with simple questions to know what the level of the knowledge of that children was. So I would start with an open question and see if they could reach the ideas that I wanted to ask, so if they could reach the question, if they couldn’t reach the question I would guide them more and follow that but sometimes you would be surprised with younger children could reach the question and that was very interesting.”

(Interview 50, Jane, Outreach Officer)

Jane, as many of the participants, recognizes she has to adapt her teaching strategy to the age and context of the students. As she is not sure about whether or not she needs to adapt her science teaching strategy differently to different age groups, she uses an open-ended questioning strategy to gauge student understanding and uses that as a point from which to elicit science learning. Jane can be seen as a hybrid practitioner as she recognizes her role as an outreach officer but adapts according to the challenges she foresees in the classroom due to her pedagogical experience.

From the arguments and reasoning that both types of participants (teachers and outreach practitioners) are giving us it is clear that outreach per se doesn’t offer an easy fix solution to the perceived issues in primary level science. Many of the teachers and science outreach practitioners
revealed a good understanding of the pedagogical knowledge relating to the different dilemmas that were presented to them. Nevertheless, they are also arguing why some strategies are not always possible. The participants put forward issues of time, curriculum and the level/age of the students they are teaching are clear constraints towards effective science pedagogy. What the data is suggesting is that many teachers and outreach practitioners are in agreement with many of the strategies the literature suggests but they identify the issues of the complex reality of the classroom. Therefore, the view of outreach as a solution to the problems of science education seems a simplistic one. The next section addresses this relationship between teachers and outreach practitioners and how this liaison can work to improve science education/outreach practice.

6.4.1.3 Dynamics of Outreach in Schools: Practice and Access

Recently, many more scientists have become involved in attempts to improve public science education. Programmes designed either to provide basic science content and creative science teaching tools for teachers or to encourage scientists to form partnerships with their local schools have mushroomed. (NeuroScience Editor, 2009, p.1)

The quote from the Neuroscience editor illustrates one of the main assumptions that are made about the role of science outreach in primary level education. The assumption is that there is not enough science at primary level education and/or that the little that exists is flawed due to the lack of the teachers’ pedagogical and scientific knowledge (Kim and Tan, 2011; Ramey-gassert, et al., 1996). Furthermore, it is assumed that outreach practitioners can improve the situation by bringing outreach initiatives (European Commission, 2007; Stocklmayer et al., 2010). As stated by Stocklmayer et al. (2010):

The informal educational sector, because of its diversity, is relatively immune to bureaucratic control and hence to ossification. It is relatively free to assist in the provision of worthwhile education by means of which young people become actively engaged in learning about science. (...) schools need to acknowledge that they will benefit from external involvement. This requires active collaborative planning for a different, inclusive mode of delivery (pp. 1, 33)

It is assumed that a flawed education system education can be fixed by a new and very different external actor. But the interview data of the participant primary level teachers and outreach practitioners problematizes these assumptions. The analyses of the different dilemmas reveal that teachers and outreach practitioners are connected pedagogically, in that they share many of the same constructivist perceptions regarding teaching and learning. Furthermore, they also share many of the tensions and challenges involved in teaching science to young children. In addition to expressing their views on pedagogy and on related challenges, some of the participants also focused their discussion specifically on the dynamics of outreach. For instance, Padraig, a teacher for six years argues:

I think the best for this type of thing [science outreach] is definitely what interests them, because they are touching everything with the curriculum but they are not really getting into it, whereas I think when someone comes into the classroom it would be better just to see something exciting and interesting, it would entice them more
John, as other participants, argues that in an outreach initiative, that their main focus is on completing relevant activities that interest the children, rather than curricular concerns e.g. here he suggests that some teachers may feel that they have limited time to do more than ‘touch’ on certain science topics. Outreach practitioners also recognize this focus of science outreach. For instance, Megan, a science outreach officer says that curriculum is “something you never have to care about in science outreach” (Interview 29, Megan, Outreach officer). Also, Sabrina, another outreach officer, recognizes that outreach does not need to be restrained by the boundaries of the curriculum:

That’s what we try and do with our outreach, it’s to create something that is more open-ended and giving students [the] time to come up with their own answers, make their own meaning, guided of course by us, but that does take time to construct that style of workshop. But maybe that’s the type of thing we can offer to teachers that would..., might normally have to teach within the boundaries. Yeah! I sometimes feel with science outreach, it goes..., it’s too much the other way and you let them go and sometimes they miss the real explanation at the end, because..., especially if they are very excited

(Interview 31, Sabrina, Outreach officer)

John, Megan, Sabrina and other participants recognize that science outreach provides workshops that engage and interest the children and are less concerned with curriculum and curricular constraints. But as Jane emphasizes, she knows this type of workshop takes time. She immediately recognizes the issues faced when trying to develop more open ended methodologies. Jane is even afraid that the students might miss the real explanation due to high levels of excitement. She knows she has limited time in the school, but she wants to bring something different to the students. At the same time, she recognizes the issues and tensions it brings to the classroom. She is being a hybrid practitioner. And other participants also recognize these issues. For instance, Charlie, when discussing if science outreach initiatives should cover different areas of science or just cover one, giving it more time, she states:

Ok, I suppose, it used to be one hour on the curriculum for science, but now with other things it is much shorter than that so I suppose, realistically, it can only be one thing at a time

(Interview 48, Charlie, Teacher for 3 years)

Charlie argues that outreach practitioners also have to be realistic about their expectations. Primary level science is allocated one hour per week at primary level, which represents 5% of the teaching time that teachers have. Charlie states that, now, with external constraints, that recently the time allocated for science is even less than this 5%, and that therefore outreach programs need to take this into account.

The fact that science only counts as 5% of teachers teaching time reveals a difference between teachers and outreach practitioners. For teachers, science represents a small part of their planning. Science is one of eleven subjects that make up the primary level curriculum in Ireland (DES, 1999). For outreach, it is very different. Many of the practitioners are “enthusiastic scientists” (Stocklmayer et al., 2010, p. 30) or outreach officers that are intrinsically motivated to carry out outreach (European Commission, 2007). These practitioners dedicate their time to preparing one or two sessions of outreach they bring to schools, which is quite different from preparing 11 subjects. Nevertheless science outreach is still considered a “sporadic and incoherent activity [that] requires
careful planning and synthesis” (Stocklmayer et al., 2010, p.30) and in which “there is significant absence of collaboration and integration” (Davison et al., 2008).

When the participant teachers discussed how science outreach works in their schools, this ad hoc-ness of outreach was visible. For instance, two teachers that belonged to the same small school had very different views regarding outreach in their school. Jessica, a teacher with 14 years of teaching shared her experience of science outreach in her school:

I’m on the board of the education centre in […], so we do a lot of, hmm, work with robotics and we have outreach scratch programs with […], so we have a lot …, we’re involved with […] originally through the fishy project, we also do projects with the science festival every year, so we present in the science festival and then we also have people come out here as part of the science festival. We have been doing the discovery primary science for six years, ok, so there is a lot of science going on

(Interview 20, Jessica, teacher for 14 years)

It is clear that Jessica has a strong connection with the different institutions responsible for science outreach in the region. Therefore, she organizes many projects and her students participate in a great number of outreach initiatives. Furthermore, Jessica states that she is part of the board of education; therefore it indicates quite careful planning with collaboration and integration of the different partners. Jessica is also a hybrid practitioner, as she is a teacher with a strong connection with outreach. Nevertheless, Karen, a teacher in the same small school, has a complete different experience when asked if it is common to have science outreach in her class:

“[Science outreach] no, because I have mainly been here and science wouldn’t be my strongest field even though we integrate a lot, like, seasons, patterns and environment. So we try to relate as much to the outside as we can.”

I: “But would you have people coming from the university to do science outreach?”

T: “No, never”

(Interview 21, Karen, teacher for 11 years)

Karen, conversely with Jessica, argues that, in her class, outreach is not common. In spite of both being in the same small rural school and Jessica having a strong relation with outreach providers, this does not seem to cross over to Karen’s class. Karen indicates a reason why this might be so. Karen argues, straight away, that science is not her strongest field. The fact that many primary level teachers are not confident about teaching science is one of the arguments being made to bring more outreach into the classroom (Stocklmayer et al., 2010). Nevertheless, with Karen, this lack of confidence in science seems to be something that also influences her decision about having outreach in her class. This disparity between the frequencies of outreach amongst teachers of the same school did not only happen between Karen and Jessica’s classes.

Anna, a teacher from a large city school reveals the outreach initiatives she has in her classroom:

[Science outreach], we had […] from the aquarium coming in, talking about different sea creatures, hmm, you had another guy come in talk about pollution and the live cycle of the salmon […] so we had a lot

(Interview 3, Anna, teacher for 7 years)
Another teacher from the same school, Beth, confirms there is a great number of outreach initiatives in the school and indicates why they get so many:

[Science outreach], yes, absolutely loads, the person you’re going to [talk to] tomorrow, was the science teacher of the year, she received an award in [...], she does the whole science initiatives in the school, she gets all of the resources, [...] she is always prompting science in the school, [...] she organizes the science experiment day, so yes, we have a lot of science.

(Interview 5, Beth, teacher for 7 years)

Again, there is a teacher that is connected with the outreach providers and actively connects the school with outreach. But at the same time, another teacher from the same school has a different view:

[Science outreach], this is..., this is the first time in my two years. But I know that, in the junior level they get more, in this class level, second class, they don’t. In this school, one of the teachers down there is very interested in science, so in that corner they get the benefit of that

(Interview 18, Isabella, Teacher for 2 years)

There is, again, a difference between teachers in the school. In this case, the teacher that has a connection with the outreach providers, shares the initiatives with the other teachers of the same level (junior). At the same time, taking into account what Isabella is saying, these initiatives do not reach the teachers that teach first and second class. Again, as with the small rural school, this indicates that having or not having outreach initiatives depends on individual teachers.

The interview data suggests that the ad hoc-ness in fact exists. In some cases there seems to be careful planning and collaboration between outreach practitioners and individual teachers that have a connection with outreach providers. Nevertheless, it seems to come down to individual teachers. This is also corroborated by the method used by this author to gain access to the different teachers for the interviews. As an incentive to take part in the interview, an hour of outreach was offered. The way in which access was obtained was described in the research journal:

This was the first school I got access to. I got access, initially, through a teacher I had met in outreach initiatives that I organised. Before this school I had tried to contact other schools by emailing the principals, rather unsuccessfully, I have to say. With this teacher it was much easier, she got the ‘OK’ from her principal and was able to point me to two other colleagues of hers. These two colleagues also agreed to participate. Their ‘OK’ to participate was much easier to obtain as I also offered to do a science outreach session with their students, in exchange for the interview. This was the key point really, as it was these sessions that enabled me to get into the school and meet more teachers. [...] So, I did the first two interviews and I was going for what I thought was the last one with teacher C. This teacher had already been referred by the other two as someone from whom I would get ‘good feedback’, as she was the one that promoted science in that school, doing science outreach sessions in other schools as well. Apart from this, this teacher was very important to my research in another way. As she was more senior in this school, and had taught the different levels along the years, she had more influence with the other teachers. So, because she and her students
appreciated the science outreach session, she advertised it to her colleagues in the school. This teacher was, then, a key point of access to my research, as she knew teachers in this school and principals in others, and her word had value, opening the doors for me in other schools. Due to teacher C’s ‘good word’, I was able to have another 16 teachers of this school answering my questions through interview. This meant that I also had to do another 16 hours of outreach in this school.

(Research Journal, February 2013)

As the research journal states, initial access was obtained by contacting teachers and not directly through the principal. Only after being referred to by a teacher did the principal give authorization for the outreach to be carried out. This was not the first time that the process worked this way. In previous outreach initiatives which the author had carried out, as a volunteer, the same process occurred. It was through the recommendation of an individual teacher to the principal, that access was granted.

Although the principals gave the official authorization, the decision for the most part came down to whether individual teachers wanted me to perform an outreach activity in their class. For instance, as the quote from the research journal highlights, the author was only able to obtain more teachers from this school after they had received a recommendation from (‘put in a good word’) from a teacher they knew and respected. Borrowing terminology more associated with research ethics, these specific teachers can be called “gatekeepers, as access was obtained to the community through introductions and by establishing a relaxed or appropriate environment” (Jensen, 2008c, p.2). Although the formal access and authorization was given by the principals, the true outreach gatekeepers were these particular teachers that advertised the outreach activity and as such negotiated access into their colleagues’ classrooms. This has specific implications for outreach, as the data indicates that for the partnerships to work, it is not enough to obtain formal access to the school. It is also important to recognize that individual teachers seem to have the keys to their classroom, therefore outreach needs to be attractive to these teachers as well. It is important to understand this dynamics of outreach gatekeepers and the two layers of access, the formal access by principals and the not less important individual access by teachers.

6.4.1.4 Dialectic reflection of the Research Participants: grassroots, innovation and pedagogy

The research objectives were twofold, relating to the discussed pedagogical application of dilemmas in the interviews. The first objective was for practitioners to reflect on issues relevant to science education and outreach. The second one was to promote dialectical thinking. For practitioners to reflect dialectically they needed to engage in deductive and inductive thinking in a process Bencze and Bowen (2009) defines as inductive-deductive dialectic immersion. Bencze himself explains the approach:

The approach involves engaging teachers in inductive and deductive thinking (dialectically) relating to science inquiry projects. To promote deductive thinking, student-teachers were explicitly presented with various perspectives about science and science inquiry [...] and, then, encouraged to evaluate (deduce). [...] At the same time, they could engage in inductive thinking, as they developed claims about science and science inquiry through experiences with their inquiry projects (p.155).
In the case of this research, deductive thinking arose when participants analysed the claims in the conceptual dichotomies, and the activities in the pedagogical dichotomies. For this, practitioners had to analyse the two dichotomic poles. In the discussion of the main themes reflected upon by the research participants this dialectic was visible. Johanne gives an example of this reasoning when she compares the student-led construction vs teacher-led construction:

They might discover the lever, they can do something else not related to the dog, so maybe actually the second one is better for smaller children because it gives them more freedom, scope, to try different things as well, actually that’s true, it actually does, doesn’t it? Whereas the first one is very... she’s only giving them one choice, you have to do this so maybe it’s too instructional, the first one. Hmm, but then again, when she goes with the dog, that’s a good example of what they should do and try to do. The second one doesn’t really say, just shows the seesaw thing, yah yah, I’m not sure, it’s a difficult one, probably for this age it’s too difficult, maybe for this age it’s too difficult, I’m not sure, I have to try that one actually.

(Interview 17, Johanne, teacher for 3 years)

It is clear that Johanne goes back and forth, in comparing and analysing the pros and cons of the two ways of conducting the activity, therefore it reflects a deductive thinking process. The next step of this reflection is when practitioners engage in inductive thinking, as they develop their own claims about the concepts, relating to their practice. This is visible in Johanne’s internal debate. When she argues that the first one is too instructional whereas the second one gives them more freedom, she is referring to her students. She does this again when she states that the dog is a good example for the students. She continues reflecting saying, that she doesn’t know, that it might be too difficult for her students. We have, then, an example of the dialectical engagement in deductive/inductive thinking (Bencze and Bowen, 2009). She ends saying she has to try with her students. When she reflects on her students she is not sure which one will work.

Jennifer also reveals this dialectic thinking when discussing the dilemma creativity/guidance:

What do I think? I don’t know what I think. I think you need to... it’s hard to know with science. I understand the second, I think it is the easier option, even you just show them an example and they’ll be able to follow this procedure all the time but what happens if that procedure doesn’t fit? So, you need to, you need to model a good procedure but you need to give them the option that they’re not stuck in this. So if another example happens and then they are going to go: “but teacher this isn’t working” and then realize teacher is not perfect. They need to be able to think outside the box otherwise they’re always going to be stuck. Other subjects as well, you teach them a certain way to do things and then they kind of stick that into one thing and they don’t apply it anywhere else, so, I think you need a bit of both. But I think that for problem solving you need to be able to see the logic of why you’re doing it. Not necessarily learning rote learning, a routine to get the best outcome out of it, I can see where you need both, why you need a little bit of both ‘cause different situations require different actions.”

(Interview 19, Jennifer, teacher for 3 years)

Jennifer starts by immediately recognizing the tension, she is not sure of her opinion. She then analyses both arguments. Jennifer recognizes the value of following a procedure; it will be the easier option. But immediately she reflects on the other option: and if the procedure does not fit? So, she wants her students to be able to follow a procedure but at the same time to think outside
Jennifer then thinks about her students, and she does not want them to be limited with a single model. Again the deductive/inductive process is working because she starts reflecting about her practice after analysing both arguments (Bencze and Bowen, 2009). Jennifer recognizes the value of divergent thinking in the solving of new problems. As stated by Mumford et al. (1991) and Runco (2004), creativity is an essential element of problem solving. Teacher Jennifer acknowledges this. She recognizes that a creative approach can help her students “not to be stuck”. But at the same time, she also understands the value of a good procedure. She negotiates this dialectic concluding that she needs to make the logic of the procedure visible to students and she needs both of the approaches for success in different situations.

Science outreach practitioners also engaged dialectically with the dilemmas. PhD student Scarlett also found the dilemma Creativity/Guidance difficult to negotiate:

It’s very difficult because they are both valid, it’s primary school you’re talking about, I think it’s important to let them be a bit creative otherwise I think if things are too rigid maybe they’ll switch off because it’s not captivating so, I think let them have a certain amount of creativity, a little bit at the start and then get into the structure of it. Work that way. When you get to second level, that, unfortunately, it becomes a little bit too difficult to have that scope because there’s a huge curriculum that they have to cover and teachers are under pressure. I know, we did have my science teacher in secondary school. At the end of the term she took a class and did what she called all the silly experiments. It was probably one the most memorable classes that we had so it could be nice if there were more scope for that. If the curriculum moved a bit towards that because I don’t agree that there is no room for creativity, otherwise no one would discover anything new

(Interview 32, Scarlett, PhD student)

Scarlett, as Jennifer, immediately acknowledges the tension. Then she offers her solution to the tension: start with the creativity and only after, go into structured approaches. The inductive reasoning comes after. She reflects further and contextualizes it to her experience. In her case, contrary to Jennifer, this contextualization is related to her experience as a student. She remembers her teacher in secondary school who, in spite of being constrained by a huge curriculum, still brought some creativity. And for Scarlett those were the “most memorable classes”. Therefore, she concludes her negotiation of the dialectic by stating that there must be space for creativity.

Other outreach practitioners also revealed this dialectic thinking. Steven, a science outreach officer argued the dilemma Inductive/Deductive Activity in the following way:

I prefer the second one [inductive] although I am not completely enamoured with it. The first one there’s no surprise or anything, the kids are told what’s going to happen or the way they are going to do it. There’s no experimentation. There was the make and play (...) but they were already told what’s going to happen before hand. It’s pretty prescribed (...). The second one, on the description they weren’t told [...] it’s much more, ok you’re going to figure it out, you’re going to do the experiment. It’s grand but what they have to make and the design of the car is prescribed. I would like them to just do and make up their minds themselves and they could learn other stuff you know about the designing and the things themselves and I think that there could have been more. That could have been done with, maybe into more, that they have to make their own creative, we’re also going to design the car as well and you put little bits and they have their own individual on to it. “
Steven starts by comparing both dialectical poles and is not really in agreement with any. He continues by deductively comparing both practices. But, then, it is visible that he starts to relate with his experience as an outreach officer and how he would do it. John negotiates the dialectic by synthesising a new activity. For Steven, a prescribed design of the car is not how he would go about it. Yes, he wants the student to reach the concept of magnetism inductively. But he also wants to enhance students’ creativity by designing their own car. In his new activity he connects the concepts of creativity and induction. By engaging in the dialectic process, Steven created a new activity in which students would be able to learn inductively and at the same time engage in divergent thinking.

In summary, the dialectical thinking about teaching and learning encouraged the participants to compare the two opposing arguments, relate to their own practice and, finally, synthesize a new argument. Some participants clearly presented this dialectical thinking:

Hmm, hmm, let me think, I’m not sure, that’s going to be a hard one, because it involves more construction rather than, which is hard like, hmm, if it was this age group a lot of it would have to be, it wouldn’t even, instructions wouldn’t even do it, you would have to do it up there and everyone would have to do it together. I think, if they had maybe like a ruler and a rock and try and try and balance, move the..., that way maybe, but I think the dog, going straight into the dog, it..., it’s going to be chaos, cutting and holes and things. I think, maybe if they have the picture and if they got it figured with the ruler it might be easier

Jennifer compares the two contradictory views, but as she imagines it with her students she only sees chaos. Therefore, she tries to synthesize a new activity that can be tailored to her students. Similarly as science outreach officer Steven, she negotiates the dialectic by developing a new activity.

6.4.2 Summary of the qualitative analyses

The qualitative data from the interviews was analysed to interpret how primary teachers and science outreach practitioners understand conceptual and pedagogical dilemmas in science teaching and learning. The coding and sorting of the interview data resulted in the identification of key themes that arose from the respondents’ discussion and reflection on the six dilemmas. The core ideas which the four themes revealed are now summarised:

The first theme, Strategies to Foster Student Learning; examined the various ways the participants articulated perspectives that best promote student learning. The arguments taken up by the participants in the interviews challenged the sound bite that teachers lack pedagogical knowledge to promote constructivist learning (Bell et al., 2009; Rocard et al., 2007; Windschitl, 2002). Many of the participants recognized that interest was an important factor to motivate students to learn. Furthermore, the participants associated the role of interest with the need to contextualize learning in students’ realities. The participants also argued that in their practice, they value students’ exploration when accompanied by the process of reflection and with scaffolding as a teaching approach. Moreover, in their analyses, the participants emphasized the importance of haptic learning: touching and feeling, and kinaesthetic exploration. Finally, some of the participants argued that exploration and learning of science is more fruitful if children are working together, collaboratively. The different strategies voiced by research participants indicated that many of these teachers have an abundance of pedagogical knowledge, in particular, in relation to a constructivist approach to learning.
The second theme, Tensions Between the Ideal and the Real; analysed why teachers often do not apply constructivist learning, in spite of having expert pedagogical knowledge of different strategies. Participants, when discussing science activities, rationalised their choice of giving less control to the student by mentioning that the lack of time, the extension of the curriculum and the age level (related task ability) of the students makes this prohibitive. The challenges that teachers face are recognized in the education literature, where curricular reforms and many science education reports (DES, 1999; European Commission., 2007) proclaim that primary level teachers are tasked with instructing science using teaching approaches that have been advanced and researched for older students. Teachers are then accused of not having content knowledge, confidence and of holding negative attitudes towards science. The analysis reported in this thesis indicates that a lack of knowledge about constructivist practice in the classroom is not responsible for these claims. As a consequence of the perceived issues, outreach officers are tasked with bringing more open-ended/inquiry pedagogies to the classroom. But experienced outreach officers also perceive similar practical issues of lack of time or the students’ age (in relation to their developing skill set). These outreach practitioners are hybrid practitioners as they reveal pedagogical knowledge of the issues that teachers face. Despite many of the teachers and science outreach practitioners revealing their pedagogical knowledge of different strategies, they argued why some strategies are not always possible. What the data suggests is that many teachers and outreach practitioners are both in agreement in relation to their preferred choice of teaching strategy and on the issues that arise due to the complex reality of the classroom. Therefore, the view of outreach as a solution to the problems of science education seems to be rather simplistic.

The third theme, Dynamics of Outreach in Schools: Practice and Access; looked at the participants’ view in relation to the role of outreach in primary level schools. The data permitted the conceptualization of the gatekeeper dynamics that were involved in gaining access into primary schools by outreach participants. Two layers of access were revealed: the formal access by principals and the equally important individual access by teachers. The formal access to schools is obtained and authorized by principals. Nevertheless, the true outreach gatekeepers were the teachers that were willing to negotiate access into their colleagues’ classrooms. Teachers from the same school revealed different relationships with outreach, varying from teachers with a strong relation with outreach providers to non-existing. The latter being more common with teachers that voiced that science was not their strongest field. With some teachers the lack of confidence in science seemed to be something that also influenced their decision about having outreach in their class. From the participants’ reasoning, it was possible to identify the outreach gatekeepers as those teachers that had an active connection with the outreach providers. These teachers shared information about the initiatives with other teachers. These teachers can be seen as hybrid practitioners as they are at the same time teachers and promoters of outreach. The data indicated that for the partnerships between teachers and outreach participants to work, that it is not enough to obtain formal access to the school, that it is also important to recognize that individual teachers have the keys to their own classroom, and as such, that outreach needs to be attractive to all teachers.

The final theme, Dialectic Reflection of the Participants: Grassroots, Innovation and Pedagogy; revealed how several of the research participants generated new understandings by engaging in the dialectical reflection by analysing the two binaries as participants in this research. The participants reflected dialectically by engaging in an inductive-deductive dialectic immersion. Deductive thinking arose when participants were asked to consider the two binaries. The participants analysed the claims presented by the conceptual dichotomies, and the activities suggested within the pedagogical dichotomies. The emerging discussion revealed that practitioners engaged in inductive thinking, as they developed their own claims about the concepts, relating to their own practice. Finally, the participants’ thinking process resulted in their creation and synthesis of new concepts that
concluded their negotiation of the dialectic. These three steps are evident in the excerpts reported upon above.
Chapter Seven: Analysis of the CLES survey
7.1. Introduction

This Chapter examines the results of the Constructivist Learning Environment Survey (CLES). The CLES was used to assess teachers’ (N=149) and science outreach practitioners’ (N=81) perceptions of classroom learning environments. The analysis presented in this Chapter addresses the quantitative research questions written below. The Chapter is divided into three sub-sections according to the division of the research questions. The chapter is divided in such a way as the analyses answer specifically each of the quantitative research questions.. The first three questions are addressed to teachers, the second three to outreach participants, and the final question compares responses of the two target groups.

- RQ 2: What perceptions do primary teachers and science outreach practitioners have in relation to the multiple dimensions of a constructivist teaching and learning environment?
  - 2.1 Does the biological sex of the primary level teachers impact the perception of a constructivist learning environment?
  - 2.2 Does school size (large/small) impact the perceptions of primary teachers in relation to a constructivist teaching and learning environment?
  - 2.3 Does having outreach initiatives in the classroom impact the perceptions of primary teachers in relation to a constructivist teaching and learning environment?
  - 2.4 Does the biological sex of the outreach practitioner have an impact on their perception of a constructivist learning environment?
  - 2.5 Do different categories of outreach practitioner have differing perceptions of a constructivist teaching and learning environments?
  - 2.6 Does frequency of outreach activities impact the perceptions of outreach practitioners in relation to a constructivist teaching and learning environment?
  - 2.7 What differences/similarities arise when teachers and outreach practitioners are asked to give their perceptions of a constructivist teaching and learning environment?

The Chapter begins with the description of the profiles of the participants in the survey. Concerning the teachers; the sex, years of experience and the size of the school they teach in is presented. In relation to the outreach practitioners; their role in the university, how often they do outreach initiatives and their sex is presented. These parameters are chosen because, in the literature, they are considered relevant for teachers and outreach practitioners (Beck et al., 2000; Bell et al., 2009; Johnson and Mclure, 2004; Thiry et al., 2008).

The Chapter continues with the discussion of the statistical analyses carried out. Ordinal logistic regression tests were completed. These tests were used to check for significant differences between the variables that characterize the profile of teachers and outreach practitioners. The final part of the Chapter uses the general linear model to compare the responses of teachers and outreach practitioners.
7.2. Research participants’ profile

7.2.1. Teachers

The CLES online survey was completed by 149 teachers. All the teachers answered more than 80% of the survey items for each scale. Therefore, all of the answers were used in the analyses since this is above the 50% guideline for the validity of each scale of the CLES survey (Bamberger and Tal, 2009). One hundred and sixteen teachers that replied to the survey were females and there were 33 male respondents, as seen table 7.1.

Table 7.1 Biological sex of the teachers

<table>
<thead>
<tr>
<th>Sex</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>33</td>
<td>22.1%</td>
</tr>
<tr>
<td>Female</td>
<td>116</td>
<td>77.9%</td>
</tr>
<tr>
<td>Total</td>
<td>149</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Table 7.2 shows the proportion of teachers that taught in large schools in comparison with those that taught in small schools. One hundred and one teachers taught in big schools whilst 46 taught in small schools. Two of the teachers did not reply to this item.

Table 7.2 Small vs. Large Schools

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>46</td>
</tr>
<tr>
<td>Large</td>
<td>101</td>
</tr>
<tr>
<td>Total</td>
<td>31</td>
</tr>
</tbody>
</table>

The last teacher descriptor in the survey asked if they had had science outreach initiatives before in their classroom, as represented in the table 7.3. The number of teachers that answered yes was 100 while 48 responded no. One teacher did not reply to this item.

Table 7.3 Outreach initiatives in the classroom

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>100</td>
</tr>
<tr>
<td>No</td>
<td>48</td>
</tr>
<tr>
<td>Total</td>
<td>148</td>
</tr>
</tbody>
</table>

The next section of this Chapter analyses the profile of the outreach practitioners that took part in the survey.
7.2.2 Outreach Practitioners

The number of outreach practitioners that took part in the survey was 81. All of the outreach practitioners answered more than 90% of the survey items. From the 81 practitioners, 38 were female and 43 were male, as represented in table 7.4.

Table 7.4 Biological sex of the Outreach practitioners

<table>
<thead>
<tr>
<th>Sex</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>43</td>
<td>53.1%</td>
</tr>
<tr>
<td>Female</td>
<td>38</td>
<td>46.9%</td>
</tr>
<tr>
<td>Total</td>
<td>81</td>
<td>100.0</td>
</tr>
</tbody>
</table>

The second categorical item used to classify the outreach practitioners was their role in the university. There were 23 post-graduate students, 13 outreach officers, 13 post-doctoral researchers, 13 lecturers, 11 senior lecturers and 8 Professors, as represented in the table 7.5.

Table 7.5 Role of the outreach practitioners

<table>
<thead>
<tr>
<th>Role</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post-graduate student (A)</td>
<td>23</td>
<td>28.4%</td>
</tr>
<tr>
<td>Outreach officer (B)</td>
<td>13</td>
<td>16.0%</td>
</tr>
<tr>
<td>Post-docs (C)</td>
<td>13</td>
<td>16.0%</td>
</tr>
<tr>
<td>Lecturer (D)</td>
<td>13</td>
<td>16.0%</td>
</tr>
<tr>
<td>Senior lecturer (E)</td>
<td>11</td>
<td>13.6%</td>
</tr>
<tr>
<td>Professor (F)</td>
<td>8</td>
<td>9.9%</td>
</tr>
<tr>
<td>Total</td>
<td>81</td>
<td>100 %</td>
</tr>
</tbody>
</table>

The last item used to classify outreach practitioners was the frequency with which they performed outreach initiatives, as represented in table 7.6. The array of frequencies chosen is illustrated in the table below. There were 14 practitioners who reported participating in outreach every week, 17 once a month or more, 43 once a year or more and seven less than once a year.

Table 7.6 Frequency of Outreach Initiatives

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Every week (1)</td>
<td>14</td>
</tr>
<tr>
<td>Less than once a week but more than once a month (2)</td>
<td>9</td>
</tr>
<tr>
<td>Once a month (3)</td>
<td>8</td>
</tr>
<tr>
<td>Less than once a month but more than once a year (4)</td>
<td>32</td>
</tr>
<tr>
<td>Once a year (5)</td>
<td>11</td>
</tr>
<tr>
<td>Less than once a year (6)</td>
<td>3</td>
</tr>
<tr>
<td>Never did one (7)</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>81</td>
</tr>
</tbody>
</table>
7.3 Quantitative results

This section presents the results of the CLES survey. As discussed in Chapter 5, the survey is divided into five scales, each one containing four items, except personal relevance, which has three. Table 7.7 represents the five dimensions.

Table 7.7 Scale descriptors and questions of the CLES Survey

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Descriptors</th>
<th>Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal relevance</td>
<td>Extent to which science is relevant to students’ everyday out-of-school experiences.</td>
<td>1. Students learn about the world inside and outside of school.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. New learning relates to experiences or questions about the world inside and outside of school.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Students learn how science is a part of their inside- and outside-of-school lives.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4. Students learn interesting things about the world inside and outside of school.</td>
</tr>
<tr>
<td>Uncertainty</td>
<td>Extent to which opportunities are provided for students to learn that science is not always certain (that scientific knowledge evolves and is culturally and socially determined; that science is about asking and answering questions, but realising that the result is not always certain).</td>
<td>5. Students learn that science cannot always provide answers to problems.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6. Students learn that scientific explanations have changed over time.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>7. Students learn that science is influenced by people’s cultural values and opinions.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8. Students learn that science is a way to raise questions and seek answers</td>
</tr>
<tr>
<td>Critical voice</td>
<td>Extent to which educators feel it is legitimate and beneficial for students to question the teachers’ pedagogical plans and methods (in terms of seeking clarification about activities, identifying barriers to their learning, questioning how and what is being taught).</td>
<td>9. Students feel safe questioning what or how they are being taught.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10. I feel students learn better when they are allowed to question what or how they are being taught.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>11. It’s acceptable for students to ask for clarification about activities that are confusing.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12. It’s acceptable for students to express concern about anything that gets in the way of their learning.</td>
</tr>
<tr>
<td>Shared control</td>
<td>Extent to which control for the design and management of learning activities is shared between the students and the teacher.</td>
<td>13. Students help me to decide how well they are learning.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>14. Students help me to decide which activities work best for them.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15. Students let me know if they need more/less time to complete an activity.</td>
</tr>
<tr>
<td>Student negotiation</td>
<td>Extent to which students have opportunities to explain and justify their ideas and to peer discuss/debate and test the viability of their own and other students’ scientific ideas</td>
<td>16. Students talk with other students about how to solve problems.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>17. Students explain their ideas to other students.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>18. Students ask other students to explain their ideas.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>19. Students are asked by others to explain their ideas.</td>
</tr>
</tbody>
</table>

The response choices for all the items were divided in a five option Lickert scale (almost always, often, sometimes, seldom, almost never). The software SPSS 20 was used for the statistical analysis. The first section presents the results for the teachers and discusses the research questions 1-4. The following section presents the results for science outreach practitioners and considers the research questions 5-8. The final section compares the results for teachers and science outreach practitioners and discusses research question 9.
7.3.1. CLES survey results for teachers

Mean and standard deviations for the CLES scales are presented in Table 7.8. Overall, the mean range was between 1.55 for critical voice and 2.62 for shared control, representing responses between almost always and sometimes.

Table 7.8. Teachers mean responses to the 5 dimensions of CLES

<table>
<thead>
<tr>
<th>Scale</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal Relevance</td>
<td>148</td>
<td>2.0591</td>
<td>0.5466</td>
</tr>
<tr>
<td>Uncertainty</td>
<td>148</td>
<td>2.6622</td>
<td>0.6912</td>
</tr>
<tr>
<td>Critical Voice</td>
<td>148</td>
<td>1.5524</td>
<td>0.5834</td>
</tr>
<tr>
<td>Shared Control</td>
<td>148</td>
<td>2.6216</td>
<td>0.6583</td>
</tr>
<tr>
<td>Student Negotiation</td>
<td>148</td>
<td>2.1588</td>
<td>0.6416</td>
</tr>
</tbody>
</table>

The extent of the relationship between teachers’ scores and three variables was evaluated. The three variables were: biological sex, whether or not a teacher has had an outreach activity in their class, and whether a school is small or large. The analysis for the five dimensions of CLES is now presented. This analysis will address the following research questions:

- RQ 2: What perceptions do primary teachers and science outreach practitioners have in relation to the multiple dimensions of a constructivist teaching and learning environment?
  - 2.1 Does the biological sex of the primary level teachers impact the perception of a constructivist learning environment?
  - 2.2 Does school size (large/small) impact the perceptions of primary teachers in relation to a constructivist teaching and learning environment?
  - 2.3 Does having outreach initiatives in the classroom impact the perceptions of primary teachers in relation to a constructivist teaching and learning environment?
Inferences for the dimension personal relevance

The four scores of each respondent to the personal relevance questions were averaged. Ordinal logistic regression was carried out to assess the impact of the factors, as represented in table 7.9. The Parameter Estimates table includes the coefficients, their standard errors, the Wald test and associated p-values (Sig.), and the 95% confidence interval of the coefficients. None of the factors were statistically significant ($p < .005$). This means that the categories biological sex, having or not outreach initiatives and size of school did not impact on the participant teachers’ perceptions of the dimension personal relevance. This means, that, on average, teachers’ perceptions were that often school science is relevant to students’ everyday out-of-school experiences.

Table 7.9 Parameter Estimates table for the dimension personal relevance

<table>
<thead>
<tr>
<th></th>
<th>Coef</th>
<th>SE Coef</th>
<th>Z</th>
<th>p (Sig.)</th>
<th>Odds Ratio</th>
<th>95% C.I. for Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biological sex</td>
<td>0.582209</td>
<td>0.358110</td>
<td>1.63</td>
<td>0.104</td>
<td>1.79</td>
<td>0.89 - 3.61</td>
</tr>
<tr>
<td>Have you ever had science outreach</td>
<td>-0.528332</td>
<td>0.316669</td>
<td>-1.67</td>
<td>0.095</td>
<td>0.59</td>
<td>0.32 - 1.10</td>
</tr>
<tr>
<td>Size of school</td>
<td>-0.587275</td>
<td>0.318486</td>
<td>-1.84</td>
<td>0.065</td>
<td>0.56</td>
<td>0.30 - 1.04</td>
</tr>
</tbody>
</table>

Inferences for the dimension uncertainty

In table 7.10 below, the parameter estimates for the dimension uncertainty are represented. The dimension uncertainty evaluates teachers’ perceptions of the extent to which opportunities are provided for students to learn that science is not always certain. The ordinal logistic regression did not reveal any significant results for this dimension. These results indicate that none of the three variables impacted teachers’ perceptions in relation to uncertainty. Teachers’ perceptions were that only sometimes do they provide opportunities for students to learn that science is not always certain.

Table 7.10 Parameter estimates for the dimension uncertainty

<table>
<thead>
<tr>
<th></th>
<th>Coef</th>
<th>SE Coef</th>
<th>Z</th>
<th>p (Sig.)</th>
<th>Odds Ratio</th>
<th>95% C.I. for Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biological sex</td>
<td>0.2641</td>
<td>0.351469</td>
<td>0.75</td>
<td>0.452</td>
<td>1.30</td>
<td>0.65 - 2.59</td>
</tr>
<tr>
<td>Have you ever had science outreach</td>
<td>-0.282</td>
<td>0.311</td>
<td>-0.91</td>
<td>0.365</td>
<td>0.75</td>
<td>0.41 - 1.39</td>
</tr>
<tr>
<td>Size of school</td>
<td>-0.354975</td>
<td>0.313591</td>
<td>1.13</td>
<td>0.258</td>
<td>0.70</td>
<td>0.38 - 1.30</td>
</tr>
</tbody>
</table>

Inferences for the dimension critical voice

Table 7.11 represents the parameter estimates for the dimension critical voice. The dimension critical voice evaluates teachers’ perceptions of the extent to which educators feel it is legitimate and beneficial for students to question the teachers’ pedagogical plans and methods. The ordinal logistic regression revealed a significant effect in the sample between small and large schools ($p = 0.013$) and between males and females ($p = 0.038$). For female teachers the mean for this dimension was 1.4828, representing a response of: almost always students feel that it is legitimate and beneficial for students to question the teachers’ pedagogical plans and methods. For males, the mean was 1.805, representing a response of often. The mean for teachers from small schools was
1.440 (almost always) and for teachers from large schools was 1.5975 (often). Teachers from small schools perceived that almost always they feel that it is legitimate and beneficial for students to question the teachers’ pedagogical plans and methods. Teachers from large schools perceived this only happens sometimes.

Table 7.11 Parameter estimates for the dimension critical voice

<table>
<thead>
<tr>
<th></th>
<th>Coef</th>
<th>SE Coef</th>
<th>Z</th>
<th>p (Sig.)</th>
<th>Odds Ratio</th>
<th>95% C.I. for Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lower</td>
<td>Upper</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biological sex</td>
<td>0.740</td>
<td>0.360</td>
<td>2.07</td>
<td>0.038</td>
<td>2.10</td>
<td>1.04 - 4.22</td>
</tr>
<tr>
<td>Have you ever had</td>
<td>-0.50</td>
<td>0.32</td>
<td>-1.60</td>
<td>0.110</td>
<td>0.60</td>
<td>0.32 - 1.12</td>
</tr>
<tr>
<td>science outreach</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size of school</td>
<td>-0.82</td>
<td>0.33</td>
<td>-2.49</td>
<td>0.013</td>
<td>0.44</td>
<td>0.23 - 0.84</td>
</tr>
</tbody>
</table>

**Inferences for the dimension shared control**

Table 7.12 describes the parameter estimates for the dimension shared control. The dimension shared control evaluates teachers’ perception of how often the control for the design and management of learning activities is shared between the students and the teacher. The ordinal logistic regression revealed a significant difference for biological sex (p=0.022). For female teachers the mean for this dimension was 2.55 and for male teachers 2.85 representing responses often and sometimes, respectively. Female teachers’ mean response was that: often control for the design and management of learning activities is shared between the students and the teacher. For male teachers, the mean response was that they only shared control sometimes. No significant effect was found for the other two variables.

Table 7.12 Parameter estimates for the dimension shared control

<table>
<thead>
<tr>
<th></th>
<th>Coef</th>
<th>SE Coef</th>
<th>Z</th>
<th>p (Sig.)</th>
<th>Odds Ratio</th>
<th>95% C.I. for Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lower</td>
<td>Upper</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biological sex</td>
<td>0.83</td>
<td>0.36</td>
<td>2.30</td>
<td>0.022</td>
<td>2.28</td>
<td>1.13 - 4.62</td>
</tr>
<tr>
<td>Have you ever had</td>
<td>-0.07</td>
<td>0.31</td>
<td>0.24</td>
<td>0.813</td>
<td>-0.93</td>
<td>0.50 - 1.72</td>
</tr>
<tr>
<td>science outreach</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size of school</td>
<td>-0.34</td>
<td>0.32</td>
<td>-1.07</td>
<td>0.285</td>
<td>0.71</td>
<td>0.38 - 1.33</td>
</tr>
</tbody>
</table>
Inferences for the dimension Student Negotiation:

Table 7.13 depicts the parameter estimates for the dimension student negotiation. The dimension student negotiation evaluates teachers’ perceptions of how often students have opportunities to explain and justify their ideas and to peer discuss/debate and test the viability of their own and other students’ scientific ideas. The ordinal logistic regression didn’t reveal any significant results for this dimension. This result indicates that biological sex, having or not having outreach initiatives and size of school does not impact on participant teachers’ perceptions of student negotiation. Teachers perceived that students often have opportunities to explain and justify their ideas and to peer discuss/debate and test the viability of their own and other students’ scientific ideas.

Table 7.13 Parameter estimates for the dimension student negotiation

<table>
<thead>
<tr>
<th></th>
<th>Coef</th>
<th>SE Coef</th>
<th>Z</th>
<th>p (Sig.)</th>
<th>Odds Ratio</th>
<th>95% C.I. for Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biological sex</td>
<td>0.402824</td>
<td>0.353905</td>
<td>1.14</td>
<td>0.255</td>
<td>1.50</td>
<td>0.75, 2.99</td>
</tr>
<tr>
<td>Have you ever had science outreach</td>
<td>-0.425952</td>
<td>0.313898</td>
<td>-1.36</td>
<td>0.175</td>
<td>0.65</td>
<td>0.35, 1.21</td>
</tr>
<tr>
<td>Size of school</td>
<td>-0.0687693</td>
<td>0.314655</td>
<td>-0.22</td>
<td>0.827</td>
<td>0.93</td>
<td>0.50, 1.73</td>
</tr>
</tbody>
</table>

Overall results for teachers

The five dimensions of the CLES survey represent five valued components of constructivism and measures teacher perceptions of their preferred classroom environment (Savasci and Berlin, 2012). The survey results address the research questions related to teachers’ perception of perceived classroom environment. The questions are set below with relevant data and related discussion.

RQ 2: What perceptions do primary teachers and science outreach practitioners have in relation to the multiple dimensions of a constructivist teaching and learning environment?

This research question is now answered in respect to teachers. Based on a comparison of the five components of personal relevance, scientific uncertainty, critical voice, shared control, and student negotiation from the CLES, it is possible to conclude that personal relevance, critical voice and student negotiation are the most frequently preferred components of constructivism. Participants shared that school science should be: relevant to student lives outside of school (personal relevance); that students should be encouraged to question the teachers’ pedagogical plans and methods (critical voice); and they also believed that it was beneficial for students to have opportunities to explain and justify their ideas and to peer discuss/debate and test the viability of their own and other students’ scientific ideas (student negotiation). This indicates that these teachers have a strong preference for collaborative learning, self-directed learning and for contextualizing learning in students’ everyday life. It shows as well that teachers’ perceptions are aligned with the Irish curricular reform. The key message from the teacher guidelines for method and approaches in science of the Irish primary level curriculum reveals:

The methods and approaches adopted should create a learning environment where children’s ideas are the starting point for science activities, practical activity is encouraged, links with the environment are fostered, children can apply
scientific concepts to everyday situations and children have an opportunity to work together, share ideas and communicate their findings (DES, 1999, p. 52)

Scientific uncertainty and shared control were the least preferred components of constructivism. Participants believed that they sometimes gave opportunities for students to learn that science is not always certain (that scientific knowledge evolves and is culturally and socially determined; that science is about asking and answering questions, but realising that the result is not always certain). They also perceived that it was beneficial sometimes to provide opportunities for students to share control with the teacher, for the design and management of learning activities. These results align with previous research carried out with science teachers. In the research developed by Savasci and Berlin (2012), science teachers preferred components of constructivism were personal relevance and student negotiation, and the least preferred were uncertainty and shared control. These results indicate that primary level teachers and science teachers had similar perceptions in relation to constructivist learning environments. This problematizes the recurrent view that the lack of development of constructivist practices by primary level teachers is due to them not having expert scientific training (Avraamidou, 2013). As these results indicate that the primary level teacher participants had similar perceptions to those of expert science teachers and that they are very aware of and favour constructivist environments for teaching science.

2.1 Does the biological sex of the primary level teachers impact the perception of a constructivist learning environment?

Significant differences in respect to teachers’ biological sex were found in the dimensions critical voice and shared control. In the dimension critical voice, male teachers had a mean response of 1.8 (often) and females of 1.4 (almost always). Male teachers perceived that in their classroom, they felt it was legitimate and beneficial for students to question teacher’s plans and methods in terms of seeking clarification about activities and identifying barriers to their learning, questioning how and what is being taught. Female teachers perceived this happened almost always. In the dimension shared control male teachers had a mean response of 2.55 (sometimes) and females of 2.25 (often). Female teachers perceived that in their classroom, students often shared with the teacher control for the design and management of learning activities. Male teachers perceived this happened sometimes. These results indicate that the participant female teachers preferred the components of constructivist learning environments more than male teachers and also that female teachers were more comfortable than males in giving students more authority in the class, in terms of structuring their own learning experience. Similar results were obtained by Beck et al. (2000) whose work showed that female primary level teachers revealed beliefs more aligned with constructivism than male primary level teachers. Further, the research carried out by Martin and Yin (1997) into classroom management revealed that male teachers were more controlling, interventionist and gave less space for students to express their wishes.

2.2 Does school size (large/small) impact the perceptions of primary teachers in relation to a constructivist teaching and learning environment?

Significant differences in respect to school size were found in the dimension critical voice. In this dimension, teachers from small schools scored on average 1.4 (almost always) whilst the answers from teachers working in large schools averaged 1.59 (often). These results indicate that teachers from small schools perceived that in their classroom, students almost always felt it was legitimate and beneficial to question teacher’s plans and methods, in terms of seeking clarification about
activities, identifying barriers to their learning, questioning how and what is being taught. Teachers from large schools perceived that this happened often. These results are supported by Ó Slatara and Morgan (2004) who argue that small schools offer more opportunities for more innovative strategies as they usually have smaller class sizes. As small schools have smaller number of students per class and a smaller number of classes overall, Ó Slatara and Morgan (2004) affirm that students have more time to complete activities, to help plan what they are going to learn and to connect learning with their out of schools lives.

2.3 Does having outreach initiatives in the classroom impact the perceptions of primary teachers in relation to a constructivist teaching and learning environment?

No significant differences were found between teachers which had experienced science outreach initiatives in their classroom and teachers that had not. These results indicate that having outreach initiatives in the school does not impact teachers’ perceptions of preferred classroom environments. The European Commission report (2007) argues that outreach can function as a catalyst to change the way science is taught in schools towards more constructivist practices. The results of this survey problematize this view since having, or not, outreach in the school did not influence teachers’ constructivist perceptions.

7.3.2. CLES survey results for science outreach practitioners

Mean and standard deviations for the CLES scales are presented in Table 7.14. Overall, the mean range was between 1.72 for personal relevance and 3.11 for shared control representing responses between often school science is relevant to students’ everyday out-of-school experiences and sometimes control for the design and management of learning activities is shared between the students and the teacher.

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal Relevance</td>
<td>81</td>
<td>1.722222222</td>
<td>0.695970545</td>
</tr>
<tr>
<td>Uncertainty</td>
<td>81</td>
<td>2.697530864</td>
<td>0.755930769</td>
</tr>
<tr>
<td>Critical Voice</td>
<td>81</td>
<td>1.839506173</td>
<td>0.683863841</td>
</tr>
<tr>
<td>Shared Control</td>
<td>81</td>
<td>3.116049383</td>
<td>0.977587182</td>
</tr>
<tr>
<td>Student Negotiation</td>
<td>81</td>
<td>2.530864198</td>
<td>0.80659655</td>
</tr>
</tbody>
</table>

The extent of the relationship between outreach practitioners’ scores and the variables biological sex, role, and frequency of outreach was evaluated. The analysis for the five dimensions of CLES is now presented. This analysis will address the following research questions:

- RQ 2: What perceptions do teachers and science outreach practitioners have in relation to the multiple dimensions of a constructivist teaching and learning environment?
  - 2.4 Does the biological sex of the outreach practitioner have an impact on their perception of a constructivist learning environment?
  - 2.5 Do different categories of outreach practitioner have differing perceptions of a constructivist teaching and learning environments?
  - 2.6 Does frequency of outreach activities impact the perceptions of outreach practitioners in relation to a constructivist teaching and learning environment?
Inferences for the dimension personal relevance

The four scores of each respondent to the personal relevance questions were averaged. Ordinal logistic regression was carried out to assess the impact of the factors represented in figure 7.15. In the Parameter Estimates table we see the coefficients, their standard errors, the Wald test and associated p-values (Sig.), and the 95% confidence interval of the coefficients. In the multinomial variables, there is a reference category. SPSS 20 assigns the lowest variable as the reference category. In the case of role, the reference category is ‘graduate student’. In the case of frequency of outreach, the reference category is every week. Each response category is paired with the reference category and interpreted in reference to it (Agresti, 1996). None of the factors were statistically significant (p < .005). This means that role, biological sex, and frequency of outreach does not impact outreach participants’ perceptions of the extent to which school science is relevant to students’ everyday out-of-school experiences. On average, science outreach practitioners’ perceptions were that science is often relevant to students’ everyday out-of-school experiences.

Table 7.15 Parameter Estimates table for personal relevance

<table>
<thead>
<tr>
<th>Role</th>
<th>Coef</th>
<th>SE Coef</th>
<th>Z</th>
<th>p (Sig.)</th>
<th>Odds Ratio</th>
<th>95% C.I. for Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graduate student</td>
<td>Reference category</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outreach officer</td>
<td>0.0980234</td>
<td>0.669357</td>
<td>0.15</td>
<td>0.884</td>
<td>1.10</td>
<td>0.30 4.10</td>
</tr>
<tr>
<td>Post-graduate</td>
<td>0.0620381</td>
<td>0.646765</td>
<td>0.10</td>
<td>0.924</td>
<td>1.06</td>
<td>0.30 3.78</td>
</tr>
<tr>
<td>Lecturer</td>
<td>-0.136240</td>
<td>0.627969</td>
<td>-0.22</td>
<td>0.828</td>
<td>0.87</td>
<td>0.25 2.99</td>
</tr>
<tr>
<td>Senior Lecturer</td>
<td>-0.159958</td>
<td>0.667113</td>
<td>-0.24</td>
<td>0.811</td>
<td>0.85</td>
<td>0.23 3.15</td>
</tr>
<tr>
<td>Professor</td>
<td>-1.21429</td>
<td>0.791264</td>
<td>-1.53</td>
<td>0.125</td>
<td>0.30</td>
<td>0.006 1.40</td>
</tr>
<tr>
<td>Biological sex</td>
<td>-.309</td>
<td>.044</td>
<td>-.70</td>
<td>-.485</td>
<td>0.73</td>
<td>0.31 1.75</td>
</tr>
<tr>
<td>Frequency of outreach</td>
<td>Reference category</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Every week</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than once a week but more than once a month</td>
<td>1.305</td>
<td>0.798</td>
<td>1.64</td>
<td>0.102</td>
<td>3.69</td>
<td>0.77 17.61</td>
</tr>
<tr>
<td>Once a month</td>
<td>1.033</td>
<td>0.801</td>
<td>1.29</td>
<td>0.197</td>
<td>2.81</td>
<td>0.58 13.49</td>
</tr>
<tr>
<td>Less than once a month but more than once a year</td>
<td>-0.045</td>
<td>0.59</td>
<td>-0.08</td>
<td>0.937</td>
<td>0.95</td>
<td>0.30 3.04</td>
</tr>
<tr>
<td>Once a year</td>
<td>0.307</td>
<td>0.757</td>
<td>0.41</td>
<td>0.685</td>
<td>1.36</td>
<td>0.31 5.98</td>
</tr>
<tr>
<td>Less than once a year</td>
<td>1.03620</td>
<td>1.16684</td>
<td>0.89</td>
<td>0.375</td>
<td>2.82</td>
<td>0.29 27.75</td>
</tr>
<tr>
<td>Never did one</td>
<td>-0.797802</td>
<td>1.06203</td>
<td>-0.75</td>
<td>0.453</td>
<td>0.45</td>
<td>0.06 3.61</td>
</tr>
</tbody>
</table>
Inferences for the dimension uncertainty

Table 7.16 presents the parameter estimates for the dimension uncertainty. The dimension uncertainty evaluates science outreach practitioners’ perceptions of how often opportunities are provided for students to learn that science is not always certain. The ordinal logistic regression did not reveal any significant results for this dimension. The results indicate that on average, science outreach practitioners’ perceptions were that they sometimes provide opportunities for students to experience that scientific knowledge evolves and is culturally and socially determined; that science is about asking and answering questions, but realising that the result is not always certain.

Table 7.16 Parameter estimates for the dimension uncertainty

<table>
<thead>
<tr>
<th>Role</th>
<th>Coef</th>
<th>SE Coef</th>
<th>Z</th>
<th>p (Sig.)</th>
<th>Odds Ratio</th>
<th>95% C.I. for Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Role</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Graduate student</td>
<td>Reference category</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outreach officer</td>
<td>0.0734263</td>
<td>0.660471</td>
<td>0.11</td>
<td>0.911</td>
<td>1.08</td>
<td>0.29</td>
</tr>
<tr>
<td>Post-graduate</td>
<td>-0.0914549</td>
<td>0.645431</td>
<td>-0.14</td>
<td>0.887</td>
<td>0.91</td>
<td>0.26</td>
</tr>
<tr>
<td>Lecturer</td>
<td>-0.0012491</td>
<td>0.624432</td>
<td>-0.00</td>
<td>0.998</td>
<td>1.00</td>
<td>0.29</td>
</tr>
<tr>
<td>Senior Lecturer</td>
<td>0.374756</td>
<td>0.665313</td>
<td>0.56</td>
<td>0.573</td>
<td>1.45</td>
<td>0.39</td>
</tr>
<tr>
<td>Professor</td>
<td>-1.16180</td>
<td>0.792296</td>
<td>-1.47</td>
<td>0.143</td>
<td>0.31</td>
<td>0.07</td>
</tr>
<tr>
<td>Biological sex</td>
<td>-0.329810</td>
<td>0.439037</td>
<td>-0.75</td>
<td>0.453</td>
<td>0.72</td>
<td>0.30</td>
</tr>
</tbody>
</table>

Inferences for the dimension Critical Voice

Table 7.17 below describes the parameter estimates for the dimension critical voice. The dimension critical voice evaluates science outreach practitioners’ perceptions of the extent to which educators feel it is legitimate and beneficial for students to question the teachers’ pedagogical plans and methods. The ordinal logistic regression showed that biological sex has a significant effect (p=0.012). For male outreach practitioners, the mean response was 1.97 and for females, 1.695, representing responses from almost always to often, respectively. This indicates that female respondents were more likely to answer that they almost always gave space for students to question the outreach practitioners’ pedagogical plans and methods. Male outreach practitioners were more likely to answer that they did it often. Frequency of outreach also revealed statistically significantly different results (p= 0.022) for the category of scientists: never did one. This refers to the scientists who replied to the survey albeit not having conducted outreach. The mean for these scientists was 3.0625, representing the response: sometimes they would give space for students to question the
outreach practitioners’ pedagogical plans and methods. For all outreach practitioners the mean was 1.839, which characterizes the response often.

Table 7.17 Parameter estimates for the dimension critical voice

<table>
<thead>
<tr>
<th>Role</th>
<th>Coef</th>
<th>SE Coef</th>
<th>Z</th>
<th>p (Sig.)</th>
<th>Odds Ratio</th>
<th>95% C.I. for Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower</td>
</tr>
<tr>
<td>Graduate student</td>
<td>Reference category</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outreach officer</td>
<td>1.08972</td>
<td>0.671995</td>
<td>1.62</td>
<td>0.105</td>
<td>2.97</td>
<td>0.80</td>
</tr>
<tr>
<td>Post-graduate</td>
<td>0.298780</td>
<td>0.646125</td>
<td>0.46</td>
<td>0.644</td>
<td>1.35</td>
<td>0.38</td>
</tr>
<tr>
<td>Lecturer</td>
<td>0.717973</td>
<td>0.628813</td>
<td>1.14</td>
<td>0.254</td>
<td>2.05</td>
<td>0.60</td>
</tr>
<tr>
<td>Senior Lecturer</td>
<td>0.569939</td>
<td>0.666907</td>
<td>0.85</td>
<td>0.393</td>
<td>1.77</td>
<td>0.48</td>
</tr>
<tr>
<td>Professor</td>
<td>0.293183</td>
<td>0.780845</td>
<td>0.38</td>
<td>0.707</td>
<td>1.34</td>
<td>0.29</td>
</tr>
<tr>
<td>Biological sex</td>
<td>1.13340</td>
<td>0.452170</td>
<td>2.51</td>
<td>0.012</td>
<td>3.11</td>
<td>1.28</td>
</tr>
<tr>
<td>Frequency of outreach</td>
<td>Reference category</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Every week</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than once a week but more than once a month</td>
<td>0.870128</td>
<td>0.778280</td>
<td>1.12</td>
<td>0.264</td>
<td>2.39</td>
<td>0.52</td>
</tr>
<tr>
<td>Once a month</td>
<td>0.636835</td>
<td>0.788242</td>
<td>0.81</td>
<td>0.419</td>
<td>1.89</td>
<td>0.40</td>
</tr>
<tr>
<td>Less than once a month but more than once a year</td>
<td>0.721161</td>
<td>0.594751</td>
<td>1.21</td>
<td>0.225</td>
<td>2.06</td>
<td>0.64</td>
</tr>
<tr>
<td>Once a year</td>
<td>1.67750</td>
<td>0.774046</td>
<td>2.17</td>
<td>0.030</td>
<td>5.35</td>
<td>1.17</td>
</tr>
<tr>
<td>Less than once a year</td>
<td>0.119695</td>
<td>1.13714</td>
<td>0.11</td>
<td>0.916</td>
<td>1.13</td>
<td>0.12</td>
</tr>
<tr>
<td>Never did one</td>
<td>-2.60216</td>
<td>1.13870</td>
<td>-2.29</td>
<td>0.022</td>
<td>0.07</td>
<td>0.01</td>
</tr>
</tbody>
</table>
Inferences for the dimension Shared Control

Table 7.18 depicts the parameter estimates for the dimension shared control. The dimension shared control evaluates science outreach practitioners’ perceptions of how often students share with the teacher control for the management of learning activities, assessment criteria, and social norms of the classroom.

The ordinal logistic regression didn’t reveal any statistically significant different results for this dimension. These results indicate that role, biological sex, and frequency of outreach does not impact participants’ perceptions of how often students share with the outreach practitioner control for the management of learning activities, assessment criteria, and social norms of the classroom. On average, science outreach practitioners’ perceptions were that sometimes students help them decide how well they are learning, which activities work best for them and if they need more/less time to complete an activity.

Table 7.18 Parameter estimates for the dimension shared control

<table>
<thead>
<tr>
<th>Role</th>
<th>Coef</th>
<th>SE Coef</th>
<th>Z</th>
<th>p (Sig.)</th>
<th>Odds Ratio</th>
<th>95% C.I. for Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graduate student</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower</td>
</tr>
<tr>
<td>Outreach officer</td>
<td>1.02920</td>
<td>0.667270</td>
<td>1.54</td>
<td>0.123</td>
<td>2.80</td>
<td>0.76</td>
</tr>
<tr>
<td>Post-graduate</td>
<td>0.33553</td>
<td>0.644526</td>
<td>0.52</td>
<td>0.603</td>
<td>1.40</td>
<td>0.40</td>
</tr>
<tr>
<td>Lecturer</td>
<td>-0.18716</td>
<td>0.623841</td>
<td>-0.30</td>
<td>0.764</td>
<td>0.83</td>
<td>0.24</td>
</tr>
<tr>
<td>Senior Lecturer</td>
<td>0.332150</td>
<td>0.664058</td>
<td>0.50</td>
<td>0.617</td>
<td>1.39</td>
<td>0.38</td>
</tr>
<tr>
<td>Professor</td>
<td>-0.918655</td>
<td>0.787411</td>
<td>-1.17</td>
<td>0.243</td>
<td>0.40</td>
<td>0.09</td>
</tr>
<tr>
<td>Biological sex</td>
<td>-0.144834</td>
<td>0.437224</td>
<td>-0.33</td>
<td>0.740</td>
<td>0.87</td>
<td>0.37</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Frequency of outreach</th>
<th>Coef</th>
<th>SE Coef</th>
<th>Z</th>
<th>p (Sig.)</th>
<th>Odds Ratio</th>
<th>95% C.I. for Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Every week</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower</td>
</tr>
<tr>
<td>Less than once a week but more than once a month</td>
<td>0.342838</td>
<td>0.769990</td>
<td>0.45</td>
<td>0.656</td>
<td>1.41</td>
<td>0.31</td>
</tr>
<tr>
<td>Once a month</td>
<td>0.989254</td>
<td>0.790033</td>
<td>1.25</td>
<td>0.211</td>
<td>2.69</td>
<td>0.57</td>
</tr>
<tr>
<td>Less than once a month but more than once a year</td>
<td>-0.108788</td>
<td>0.590039</td>
<td>-0.18</td>
<td>0.854</td>
<td>0.90</td>
<td>0.28</td>
</tr>
<tr>
<td>Once a year</td>
<td>0.0984305</td>
<td>0.753536</td>
<td>0.13</td>
<td>0.896</td>
<td>1.10</td>
<td>0.25</td>
</tr>
<tr>
<td>Less than once a year</td>
<td>-0.871697</td>
<td>1.14110</td>
<td>-0.76</td>
<td>0.445</td>
<td>0.42</td>
<td>0.04</td>
</tr>
<tr>
<td>Never did one</td>
<td>-0.802870</td>
<td>1.06468</td>
<td>-0.75</td>
<td>0.451</td>
<td>0.45</td>
<td>0.06</td>
</tr>
</tbody>
</table>
**Inferences for the dimension Student Negotiation**

Table 7.19 represents the parameter estimates for the dimension student negotiation. The dimension student negotiation evaluates science outreach practitioners’ perceptions of the extent to which students have opportunities to explain and justify their ideas and to peer discuss/debate and test the viability of their own and other students’ scientific ideas. The ordinal logistic regression revealed a statistically significant different result in relation to role. Senior lectures response mean was 2.9, whilst for all other outreach practitioners the mean was 2.56, representing responses from sometimes to often. Therefore, the mean response reported by senior lecturers was that in their outreach initiatives, sometimes students have opportunities to explain and justify their ideas and to peer discuss/debate and test the viability of their own and other students’ scientific ideas. The remainder of outreach practitioners mean response was that this happened often.

**Table 7.19 Parameter estimates for the dimension student negotiation**

<table>
<thead>
<tr>
<th>Role</th>
<th>Coef</th>
<th>SE Coef</th>
<th>Z</th>
<th>p (Sig.)</th>
<th>Odds Ratio</th>
<th>95% C.I. for Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lower</td>
<td>Upper</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Graduate student</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outreach officer</td>
<td>0.0352078</td>
<td>0.659120</td>
<td>0.05</td>
<td>0.957</td>
<td>1.04</td>
<td>0.28</td>
</tr>
<tr>
<td>Post-graduate</td>
<td>-0.683310</td>
<td>-1.06</td>
<td>0.647075</td>
<td>0.291</td>
<td>0.50</td>
<td>0.14</td>
</tr>
<tr>
<td>Lecturer</td>
<td>-1.81740</td>
<td>0.650119</td>
<td>-2.80</td>
<td>0.005</td>
<td>0.16</td>
<td>0.05</td>
</tr>
<tr>
<td>Senior Lecturer</td>
<td>-1.36785</td>
<td>0.678358</td>
<td>-2.02</td>
<td>0.044</td>
<td>0.25</td>
<td>0.07</td>
</tr>
<tr>
<td>Professor</td>
<td>-1.12488</td>
<td>0.788322</td>
<td>-1.43</td>
<td>0.154</td>
<td>0.32</td>
<td>0.07</td>
</tr>
<tr>
<td>Biological sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.162950</td>
<td>0.437138</td>
<td>0.37</td>
<td>0.709</td>
<td>1.18</td>
<td>0.50</td>
</tr>
</tbody>
</table>

**Overall results for science outreach practitioners**

The survey results address the research questions related to outreach practitioners’ perception of their classroom environment. The questions are set below with relevant data and related discussion

**RQ 2:** What perceptions do teachers and science outreach practitioners have in relation to the multiple dimensions of a constructivist teaching and learning environment?

This research question is now answered in respect to science outreach practitioners. Positioned on a comparison of the CLES’s five components, it is possible to conclude that personal relevance
and critical voice are the most frequently preferred dimensions of constructivism for science outreach practitioners. Participants shared that school science should be relevant to students’ everyday out-of-school experiences (personal relevance). They also indicated that it is legitimate and beneficial for students to question the teachers’ pedagogical plans and methods, in terms of seeking clarification about activities, identifying barriers to their learning, questioning how and what is being taught (critical voice). These findings reveal that the participant outreach practitioners have views congruent with two of the main objectives put forward for outreach activities. McCallie et al. (2009) affirm that one of the main objectives of science outreach practices is to “make apparent the relevance and importance of science to everyday life and society” (p.21). This objective aligns itself with the personal relevance dimension of constructivism that outreach practitioners favoured. Furthermore, Bell et al. (2009) argue that science outreach “should also focus on helping learners become aware of and express their own ideas, giving them new information and models that can build on or challenge their intuitive ideas.” (p.34). It is evident that the view put forward by Bell et al. (2009) is the one represented by the constructivist dimension critical voice, which the participant outreach practitioners favour.

Scientific uncertainty, student negotiation and shared control were the least preferred components of constructivism, as advocated by the outreach practitioners. Participants shared that there were sometimes opportunities for students to experience that scientific knowledge evolves and is culturally and socially determined; that science is about asking and answering questions, but realising that the result is not always certain. They also believe that there were sometimes opportunities for students to share the control for the design and management of learning activities. There is no previous research in relation to constructivist perceptions of outreach practitioners. Nevertheless, outreach practitioners may be compared to science teachers in a sense, in terms of their shared scientific background. Savasci and Berlin (2012) have shown in their research that science teachers least preferred dimensions of constructivism are uncertainty and shared control. This data suggests that both outreach practitioners and science teachers have doubts about sharing with the students, control for the design and management of learning activities. Furthermore, both groups have also doubts about promoting uncertainty in science (providing opportunities for students to learn that science is not always certain). The lack of promotion of scientific uncertainty has been identified in previous reports regarding societal issues. Professor Tim Palmer from the Royal Society (2010, p.6) has stated that “recent public debate about climate change has undoubtedly demonstrated that uncertainty in science needs to be more effectively explained”.

2.4 Does the biological sex of the outreach practitioner have an impact on their perception of a constructivist learning environment?

Biological sex played a significant role in the dimension critical voice. For male practitioners, the mean response was 1.97 and for female practitioners, 1.695, representing responses from almost always to often. This indicates that male respondents were more likely to answer that they often feel it is legitimate and beneficial for students to question the teachers’ pedagogical plans and methods (in terms of seeking clarification about activities, identifying barriers to their learning, questioning how and what is being taught). Females were more likely to answer they did it almost always. Although there isn’t any previous research carried out with science outreach practitioners in relation to the CLES, this result aligns with research carried out with teachers here and in the literature. Beck et al. (2000) reported that female primary level teachers revealed beliefs which are more aligned with constructivism than their male counterparts.
2.5 Do different categories of outreach practitioner have differing perceptions of a constructivist teaching and learning environment?

Statically significant differences were identified, concerning the role an outreach practitioner has in the university and their perception of the dimension student negotiation. For this dimension senior lectures had a mean response of 2.9 (sometimes). The mean response for all outreach practitioners was 2.56 (from often to sometimes). Senior lecturers perceived that sometimes students shared control of the design and management of the learning activities. These results indicate that senior lectures are less likely to share control of the learning activities than the remainder types of science outreach practitioners. Shared control is a key component of constructivism and involves having the students helping the outreach practitioner to decide how well they are learning, which activities work best for them and if they need more/less time to complete an activity (Johnson and McLure, 2004). The results indicate that senior lecturers might transfer to outreach initiatives a lecturing style of teaching common in higher education, one which gives less control to students (Thiry et al., 2008).

2.6 Does frequency of outreach impact the perceptions of outreach practitioners in relation to a constructivist teaching and learning environment?

Frequency of outreach revealed significant difference within the dimension critical voice. Scientists that never did outreach had a mean score of 3.06 (sometimes) for critical voice whilst the mean response for all practitioners was 1.839 (often). Scientists that never performed outreach activities perceived that only sometimes educators feel it is legitimate and beneficial for students to question the teachers’ pedagogical plans and methods (in terms of seeking clarification about activities, identifying barriers to their learning, questioning how and what is being taught). The remainder of outreach practitioners felt that this happened often. These results are supported by Thiry et al. (2008) who argue that scientists that are new to outreach tend to develop practices less congruent with constructivist practices and are not confident in giving more control to students. Therefore, scientists that are new to outreach are less likely to develop one of the key aspects of informal learning as stated by Bell et al. (2009) that involves assisting students in becoming aware of and expressing their own ideas, giving them new information and models that can build on or challenge their intuitive ideas, i.e., critical voice.

The next section presents the results of the combined analysis of the teachers’ and outreach practitioners’.

4.3.1 Teachers and Outreach Practitioners

Statistical tests were carried out to compare teachers and outreach practitioners’ perceptions, in an effort to address the following research question:

2.7 What are the differences and similarities between teachers’ and outreach practitioners’ perceptions of constructivist teaching and learning environments?

A univariate General Linear Model (GLM) was used to compare teachers’ and outreach practitioners’ responses. The following is the result of a univariate GLM procedure with response being mean score, and inputs being the factors biological sex and role (teacher/outreach
practitioner). The sum of the results for the five dimensions of the survey was averaged to obtain the overall mean score. Biological sex was added to the model as there was a relevant difference between the data sets. The percentage of male outreach practitioners in the science outreach practitioners data set was 53% whilst in the teachers’ dataset; only 23% of the teachers’ respondents were males.

Table 7.20: Univariate General Linear Model

<table>
<thead>
<tr>
<th></th>
<th>Type III sum of squares</th>
<th>df</th>
<th>mean square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Model</td>
<td>2.820</td>
<td>2</td>
<td>1.410</td>
<td>5.997</td>
<td>0.03</td>
</tr>
<tr>
<td>Intercept</td>
<td>1022.013</td>
<td>1</td>
<td>1022.013</td>
<td>4346.511</td>
<td>0.00</td>
</tr>
<tr>
<td>Role</td>
<td>417</td>
<td>1</td>
<td>0.417</td>
<td>1.774</td>
<td>0.184</td>
</tr>
<tr>
<td>Biological sex</td>
<td>1.591</td>
<td>1</td>
<td>1.591</td>
<td>6.765</td>
<td>0.010</td>
</tr>
<tr>
<td>Error</td>
<td>53.140</td>
<td>226</td>
<td>0.235</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1208.474</td>
<td>229</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected Total</td>
<td>55.960</td>
<td>228</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. R Squared =0.050 (Adjusted R Squared =0.042)

The univariate GLM revealed a statistically significant difference for biological sex (p-value = 0.010) but no statistically significant difference between the responses for teachers and outreach practitioners (p-value = 0.184), as evident in Table 7.20.
The histogram of the residuals looks appropriate because it has a normal distribution, as represented in figure 7.1, which supports the results of the GLM model. Nonetheless, normality of the error distributions in the underlying model is not crucial as the sample size is large (Pallone, 2005).

Figure 7.1 Histogram of the residuals of the mean scores of teachers’ and outreach practitioners responses

If biological sex had not been included in the model, the result of the GLM would be different, as represented in table 7.21.

Table 7.21 Univariate General Linear Model

<table>
<thead>
<tr>
<th>Type III sum of squares</th>
<th>df</th>
<th>mean square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Model</td>
<td>1.229</td>
<td>2</td>
<td>1.229</td>
<td>5.099</td>
</tr>
<tr>
<td>Intercept</td>
<td>1075.024</td>
<td>1</td>
<td>1075.024</td>
<td>4458.717</td>
</tr>
<tr>
<td>Role</td>
<td>1.229</td>
<td>1</td>
<td>1.229</td>
<td>5.099</td>
</tr>
<tr>
<td>Error</td>
<td>54.731</td>
<td>227</td>
<td>0.241</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1208.474</td>
<td>229</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected Total</td>
<td>55.960</td>
<td>228</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. R Squared =0.022 (Adjusted R Squared =0.018)
The univariate GLM reveals that there is a difference between teachers and outreach practitioners. This result is related to the fact that biological sex and whether a person is a teacher or outreach practitioner are strongly correlated. There is a significant relationship between the variables biological sex and role. A cross-tabulation of the data on these variables appears below (table 7.22). The p-value for the test of no association between the two variables is 0.000+. Therefore, one can conclude that a relationship exists.

<table>
<thead>
<tr>
<th>Sex</th>
<th>Male</th>
<th>Female</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>teacher</td>
<td>32</td>
<td>116</td>
<td>148</td>
</tr>
<tr>
<td>outreach</td>
<td>43</td>
<td>38</td>
<td>81</td>
</tr>
<tr>
<td>Total</td>
<td>75</td>
<td>154</td>
<td>229</td>
</tr>
</tbody>
</table>

Cell Contents: Count

Pearson Chi-Square = 23.532, DF = 1, P-Value = 0.000
Likelihood Ratio Chi-Square = 23.124, DF = 1, P-Value = 0.000

The general comparison between teachers’ and outreach practitioners’ responses yield two main results: when biological sex is taken into account, there is no significant difference between teachers and outreach practitioners. This means that, in a model corrected for biological sex, there are no significant differences for the overall scores of teachers and science outreach practitioners. On the other hand, if biological sex is not included, there is a difference between the two. This indicates that the statically significant difference between the two data sets is due to biological sex. Male respondents revealed perceptions of the preferred classroom environment less aligned with constructivism than female respondents. Again, this is aligned with previous research that revealed that female primary level teachers showed beliefs more aligned with constructivism than their male counterparts (Beck et al., 2000).

Although the analysis of the overall mean result of the five dimensions of the CLES didn’t reveal significant differences, significant differences were found when each of the five valued dimensions of constructivism were analysed individually. The next section compares the scores of teachers and outreach practitioners for each of the five dimensions.

**Comparison of teachers and outreach practitioners for the dimension Personal Relevance**

The descriptive statistics for this variable are presented in table 7.23

<table>
<thead>
<tr>
<th>Biological sex</th>
<th>N</th>
<th>Mean</th>
<th>Std Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>75</td>
<td>1.9647</td>
<td>0.7015</td>
</tr>
<tr>
<td>Female</td>
<td>154</td>
<td>1.9367</td>
<td>0.5814</td>
</tr>
<tr>
<td>Role</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teacher</td>
<td>148</td>
<td>2.0591</td>
<td>0.5466</td>
</tr>
<tr>
<td>Outreach</td>
<td>81</td>
<td>1.7222</td>
<td>0.6960</td>
</tr>
</tbody>
</table>
An univariate GLM test was used to compare the two groups with responses being the mean score and inputs being the factors sex and role, as represented in table 7.24.

Table 7.24 General linear model analysis of variance for personal relevance

<table>
<thead>
<tr>
<th></th>
<th>DF</th>
<th>Seq SS</th>
<th>Adj SS</th>
<th>Adj Ms</th>
<th>F</th>
<th>p (Sig.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biological sex</td>
<td>1</td>
<td>0.050</td>
<td>0.8095</td>
<td>0.8095</td>
<td>2.23</td>
<td>0.136</td>
</tr>
<tr>
<td>Role</td>
<td>1</td>
<td>6.7462</td>
<td>6.7462</td>
<td>6.7462</td>
<td>18.62</td>
<td>0.000</td>
</tr>
<tr>
<td>Error</td>
<td>226</td>
<td>81.8607</td>
<td>81.8607</td>
<td>0.3622</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>228</td>
<td>88.6119</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

For completeness and more reassurance, a natural log transformation of the responses was carried out and the analysis was re-run to ensure that the residuals look more like a sample from a normal distribution. Although normality was still rejected, this is not important due to the large sample size (with a large sample size one will always reject normality). The results obtained were consistent with those presented in table 8.23 above. The log transformation analysis gave a biological sex p-value of 0.091 and outreach/teacher p-value again of 0.000+. This indicates that there was a statistically significant difference between teachers’ and outreach practitioners’ responses for the dimension personal relevance but not between males and females. Next, an analysis was performed to see if an ordinal logistic regression obtained consistent outcomes to lend further credence to the results, as illustrated in table 7.25. The results for the dimension personal relevance are explained after the table 7.25.

Table 7.25 Ordinal logistic regression for personal relevance

<table>
<thead>
<tr>
<th></th>
<th>Coef</th>
<th>SE Coef</th>
<th>Z</th>
<th>p (Sig.)</th>
<th>Odds Ratio</th>
<th>95% C.I. for Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower</td>
</tr>
<tr>
<td>Biological sex</td>
<td>0.333701</td>
<td>0.261407</td>
<td>1.28</td>
<td>0.202</td>
<td>1.40</td>
<td>0.84</td>
</tr>
<tr>
<td>Role</td>
<td>1.38107</td>
<td>0.268785</td>
<td>5.14</td>
<td>0.000</td>
<td>3.98</td>
<td>2.35</td>
</tr>
</tbody>
</table>

A statistically significant difference was present between outreach practitioners and teachers (p-value <0.000+) but no difference between male and female in the population from which the sample was taken (p-value = 0.202). The results are therefore consistent with the GLM model. The mean response for teachers was 2.05, representing that teachers believe that often science is relevant to students’ everyday out-of-school experiences. For outreach practitioners the mean response was 1.72, representing a response from almost always to often. These results indicate that science outreach practitioners preferred the constructivist dimension of personal relevance more than teachers (science is relevant to students’ everyday out-of-school experiences). Therefore, outreach practitioners are more likely to develop practices in which students learn about the world inside and outside of school and that science is a part of their inside- and outside-of-school lives.

Next, the variance for the dimension uncertainty was analysed.
Comparison of teachers and outreach personnel for the dimension Uncertainty

The GLM test was used to test for the dimension uncertainty.

Table 7.26 General linear model analysis of variance for uncertainty

<table>
<thead>
<tr>
<th></th>
<th>DF</th>
<th>Seq SS</th>
<th>Adj SS</th>
<th>Adj Ms</th>
<th>F</th>
<th>p (Sig.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biological sex</td>
<td>1</td>
<td>0.2461</td>
<td>0.2079</td>
<td>0.2079</td>
<td>0.41</td>
<td>0.525</td>
</tr>
<tr>
<td>Role</td>
<td>1</td>
<td>0.093</td>
<td>0.093</td>
<td>0.093</td>
<td>0.02</td>
<td>0.893</td>
</tr>
<tr>
<td>Error</td>
<td>226</td>
<td>115.7398</td>
<td>115.7398</td>
<td>0.5121</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>228</td>
<td>116.0131</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The results show that neither of the two input variables seems to have an effect on uncertainty (p<0.05), as seen in table 7.26. The ordinal logistic regression corroborated this result, as described in the table 7.27. The implications of the results is explained after the table 7.27.

Table 7.27 Ordinal logistic regression for uncertainty

<table>
<thead>
<tr>
<th></th>
<th>Coef</th>
<th>SE Coef</th>
<th>Z</th>
<th>p (Sig.)</th>
<th>Odds Ratio</th>
<th>95% C.I. for Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lower</td>
</tr>
<tr>
<td>Biological sex</td>
<td>0.150374</td>
<td>0.259650</td>
<td>0.58</td>
<td>0.562</td>
<td>1.16</td>
<td>0.70</td>
</tr>
<tr>
<td>Role</td>
<td>0.0526384</td>
<td>0.254701</td>
<td>0.21</td>
<td>0.836</td>
<td>1.05</td>
<td>0.64</td>
</tr>
</tbody>
</table>

The results of the above ordinal logistic analysis (0.562, 0.836) are similar to those of the GLM analysis (0.525, 0.893). Neither of the two input variables shows evidence of having an effect on uncertainty. These results indicate that science outreach practitioners and teachers didn’t differ significantly in their preference for the dimension of constructivism uncertainty. Both groups perceived that sometimes they provide opportunities for students to learn that science is not always certain.

Comparison of teachers and outreach personnel for the dimension critical voice

The above tests were repeated for the dimension critical voice. First, the GLM test was conducted, as represented in figure 7.28.

Table 7.28 General linear model analysis of variance for critical voice

<table>
<thead>
<tr>
<th></th>
<th>DF</th>
<th>Seq SS</th>
<th>Adj SS</th>
<th>Adj Ms</th>
<th>F</th>
<th>p (Sig.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biological sex</td>
<td>1</td>
<td>6.7529</td>
<td>4.1630</td>
<td>4.1630</td>
<td>11.30</td>
<td>0.01</td>
</tr>
<tr>
<td>Role</td>
<td>1</td>
<td>1.7262</td>
<td>1.7262</td>
<td>1.7262</td>
<td>4.68</td>
<td>0.031</td>
</tr>
<tr>
<td>Error</td>
<td>226</td>
<td>83.2823</td>
<td>83.2823</td>
<td>0.3685</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>228</td>
<td>91.7615</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In this test, statistical evidence revealed that both biological sex and role have an effect (p-value 0.001 and 0.031, respectively). Again, there is consistency of the GLM and ordinal logistic regression analyses, as seen in table 7.29. Both have significant results for sex and role. The implication of the results is explained after the table 7.29.
The mean for teachers in this dimension was 1.55 representing a response from almost always to often. The mean response from teacher respondents indicates that they feel that almost always/often it is legitimate and beneficial for students to question the teachers’ pedagogical plans and methods. For outreach practitioners the mean was 1.84, which indicates that this only happens often. For the variable biological sex, the mean for all female practitioners was 1.4 representing a response of almost always. For males it was 2.01 representing a response of often. Female respondents (teachers and outreach practitioners) shared that almost always it is legitimate and beneficial for students to question the teachers’ pedagogical plans and methods. Male respondents believed this only happens often.

These results show that teachers favour the constructivist dimension of critical voice more than science outreach practitioners despite both groups favouring it. Further, it indicates, that female participants preferred this dimension more than male participants. Overall, these participants believed that it was beneficial for students to question pedagogical plans.

Comparison of teachers and outreach personnel for the dimension Shared Control

The GLM test for the dimension shared control is represented in table 7.30.

Table 7.30 General linear model analysis of variance for shared control

<table>
<thead>
<tr>
<th>DF</th>
<th>Seq SS</th>
<th>Adj SS</th>
<th>Adj Ms</th>
<th>F</th>
<th>p (Sig.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biological sex</td>
<td>1</td>
<td>6.8720</td>
<td>2.4301</td>
<td>2.4301</td>
<td>3.99</td>
</tr>
<tr>
<td>Role</td>
<td>1</td>
<td>8.3128</td>
<td>8.3128</td>
<td>8.3128</td>
<td>13.64</td>
</tr>
<tr>
<td>Error</td>
<td>226</td>
<td>137.7497</td>
<td>137.7497</td>
<td>0.6095</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>228</td>
<td>152.9345</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In both the GLM (table 7.30) and ordinal logistic regression analyses (table 7.31), role reveals a significant effect on the data. The mean response of teachers for this dimension was 2.62 representing the response: often to sometimes students share with the teacher control for the design and management of learning activities. The mean response of outreach practitioners for this dimension was 3.11, representing a response of sometimes. In relation to biological sex, the GLM test gives a p-value of 0.047 while the ordinal logistic analyses results in a p-value of 0.09. Therefore, it is not possible to state a significant effect. These results indicate that teachers preferred the constructivist dimension of shared control (share with the teacher control for the design and management of learning activities) more than science outreach practitioners.
Table 7.31 Ordinal logistic regression for shared control

<table>
<thead>
<tr>
<th></th>
<th>Coef</th>
<th>SE Coef</th>
<th>Z</th>
<th>p  (Sig.)</th>
<th>Odds Ratio</th>
<th>95% C.I. for Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Biological sex</strong></td>
<td>0.443644</td>
<td>0.261475</td>
<td>1.70</td>
<td>0.090</td>
<td>1.56</td>
<td>0.93, 2.60</td>
</tr>
<tr>
<td><strong>Role</strong></td>
<td>-1.13617</td>
<td>0.264632</td>
<td>-4.29</td>
<td>0.000</td>
<td>0.32</td>
<td>0.19, 0.54</td>
</tr>
</tbody>
</table>

Comparison of teachers and outreach personnel for the dimension student negotiation

For this dimension, with respect to biological sex, the GLM test gave a p-value of 0.043, as seen in the table 7.32, while for the ordinal logistic regression; the p value is 0.071, as described in the table 7.33.

Table 7.32 General linear model analysis of variance for student negotiation

<table>
<thead>
<tr>
<th></th>
<th>DF</th>
<th>Seq SS</th>
<th>Adj SS</th>
<th>Adj Ms</th>
<th>F</th>
<th>p  (Sig.)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Biological sex</strong></td>
<td>1</td>
<td>4.8999</td>
<td>2.0330</td>
<td>2.0330</td>
<td>4.16</td>
<td>0.043</td>
</tr>
<tr>
<td><strong>Role</strong></td>
<td>1</td>
<td>4.3806</td>
<td>4.3806</td>
<td>4.3806</td>
<td>8.96</td>
<td>0.003</td>
</tr>
<tr>
<td><strong>Error</strong></td>
<td>226</td>
<td>110.5334</td>
<td>110.5334</td>
<td>0.4891</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>228</td>
<td>119.8139</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In relation to role, the p-values are highly consistent (0.003 for GLM and 0.006 for ordinal logistic). The p-values tell us that there is strong evidence of a difference between outreach practitioners and teachers in a model that has been adjusted for the effect of biological sex. The mean response for teachers was 2.16 representing that their perception was that students often have opportunities to explain and justify their ideas and to peer discuss/debate and test the viability of their own and other students’ scientific ideas. For outreach practitioners the mean response was 2.53 representing a response from often to sometimes. This shows that teachers favoured more towards the constructivist dimension of student negotiation than science outreach practitioners. Teachers therefore asserted even more than outreach practitioners, that students should have opportunities to explain and justify their ideas and to peer discuss/debate and test the viability of their own and other students’ scientific ideas.

Table 7.33 Ordinal logistic regression for student negotiation

<table>
<thead>
<tr>
<th></th>
<th>Coef</th>
<th>SE Coef</th>
<th>Z</th>
<th>p  (Sig.)</th>
<th>Odds Ratio</th>
<th>95% C.I. for Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Biological sex</strong></td>
<td>0.472581</td>
<td>0.261379</td>
<td>1.81</td>
<td>0.071</td>
<td>1.60</td>
<td>0.96, 2.68</td>
</tr>
<tr>
<td><strong>Role</strong></td>
<td>-0.704274</td>
<td>0.258506</td>
<td>-2.72</td>
<td>0.006</td>
<td>0.49</td>
<td>0.30, 0.82</td>
</tr>
</tbody>
</table>
Overall comparison between teachers and outreach practitioners

The CLES results allowed the comparison of teachers’ and outreach participants’ perceptions in relation to five valued components of constructivism (Savasci and Berlin, 2012) and therefore address the research question:

2.7 What differences/similarities arise when teachers and outreach practitioners are asked to give their perceptions of a constructivist teaching and learning environments?

Significant differences between teachers and outreach practitioners were found within four of the five dimensions (personal relevance, critical voice, shared control and student negotiation).

In the dimension personal relevance, teachers’ mean response was 2.05 (often) whilst outreach practitioners was 1.72 (from almost always to often). Teachers perceived that school science was often relevant to students’ everyday out-of-school experiences whilst outreach practitioners argued this happens in their initiatives almost always to often. Therefore both groups are aligned with the Irish primary level curriculum for science (DES, 1999) that argues that students should apply science concepts to everyday situations. The fact that outreach practitioners agree even more with personal relevance than teachers indicates they recognize one of the main objectives of science outreach as stated by McCallie et al. (2009, p.21): “make apparent the relevance and importance of science to everyday life and society”.

In the dimension critical voice, the teachers mean score was 1.55 (from almost always to often) and outreach practitioners was 1.84 (from almost always to often, but closer to often). This indicates that teacher respondents were more likely to answer that they almost always felt that it is legitimate and beneficial for students to question the teachers’ pedagogical plans and methods; in terms of seeking clarification about activities, identifying barriers to their learning, questioning how and what is being taught. For the most part, both outreach practitioners and teachers felt that students should have more control of their learning and as such, that it is ‘often to almost always’ legitimate and beneficial to allow students to question teachers’ plans and methods, with outreach practitioners leaning slightly more towards often than almost always on occasion.

For shared control the mean response of teachers was 2.62 (from often to sometimes) and outreach practitioners was 3.11 (sometimes). Teachers and outreach practitioners perceived that only sometimes, control for the design and management of learning activities is shared between the students and the teacher, but teachers were more inclined towards often. Shared control is the dimension of constructivism for which both types of participants were less aligned with. Previous research carried out with science teachers by Savasci and Berlin (2012) revealed similar results. This data suggests that outreach practitioners and primary level teachers share with science teachers the uncertainties in sharing control with the students, for the design and management of learning activities.

Lastly, for student negotiation, teachers’ average score was 2.16 (often) and outreach practitioners was 2.53 (from often to sometimes). Teachers perceived that students often have opportunities to explain and justify their ideas and to peer discuss/debate and test the viability of their own and other students’ scientific ideas, whilst outreach practitioners believe these opportunities occur from often to sometimes. These results indicate that teachers are more aligned with the Irish primary level curriculum when it is argued that children should “have an opportunity to work together, share ideas and communicate their findings” (DES, 1999, p. 52).

Based on a comparison of the CLES’s five components, it is possible to conclude that teachers reported preferring more than outreach practitioners three of the five valued components of constructivist practice (critical voice, shared control and student negotiation), although both groups
were overall favourable. Only in one of the dimensions, outreach practitioners were more inclined
to constructivist practices than teachers (personal relevance). These results problematize some of
the assumptions made in science outreach. It is assumed that outreach has the capability of
developing more constructivist practices as outreach programmes usually bring hands on inquiry
based activities to schools (Bell et al., 2009; European Commission, 2007; Thiry et al., 2008). The
results of this survey suggest that in three valued components of constructivism, outreach
practitioners have perceptions less aligned with constructivist practices than teachers. Therefore,
one can question if outreach will develop more constructivist practices in schools than teachers will.
Nevertheless, outreach practitioners were still favourable towards constructivist practice, although
to some slight degree, not as much as teachers. As outreach practitioners do not suffer from some
of the constraints teachers do (e.g. curriculum) and still revealed perceptions favourable to
constructivism they are still in a position to instil constructivist learning environments in the
classroom.

Finally, when analysing the differences between outreach practitioners and teachers
another variable was relevant, the biological sex of participants. Biological sex was revealed cause a
statistically significant difference across the overall results of CLES. These results indicate that both
male outreach practitioners and male teachers are less favourable (significantly so) to constructivist
practices than females. These results are congruent with previous research carried out with science
teachers (Beck et al., 2000) and research that analysed classroom management research (Martin and
Yin 1997). Both reported results that indicate that male teachers develop practices less aligned with
constructivism.

This Chapter analysed the results of the CLES survey. Furthermore, it addressed the research
questions based on the multiple dimensions of the constructivist classroom. The next Chapter
synthesizes the results from CLES and the semi-structured interviews.
Chapter Eight: Conclusion
8.1 Conclusions

This study set out to explore and compare the views of teachers and science outreach practitioners in relation to constructivist teaching and learning in science education. To achieve this, a dialectic, pragmatic framework was applied to the research. The pragmatic methodological design relied on using a “mixture of methods and procedures that work best” to address the aim of the study (Johnson and Onwuegbuzie, 2004, p. 17). Pragmatism argues the compatibility thesis, which sustains that quantitative and qualitative methods can be combined productively in a research study (Howe, 1988). The pragmatic objective is to find workable solutions to philosophical problems, thus rejecting binary choices (Johnson and Onwuegbuzie, 2004). This dialectic stance implies taking “quantitative and qualitative methods seriously but then developing a synthesis” (Teddlie and Tashakkori, 2009, p.73). The dialectical mixing of methods is relevant to address the aim of the study, as it employs deductive and inductive logics (Johnson and Onwuegbuzie, 2004). The methods used were the CLES survey and a semi-structured interview. The analyses of the results yielded from the mixed methods approach allowed one to problematize the views that undermine the knowledge, perceptions and practices of primary level teachers and the possibilities of science outreach as an easy fix for science at primary level. Three different layers of analyses were employed and the following sub-sections present the conclusions drawn from this research, interwoven with an emphasis on contribution to new knowledge.

First layer: outcomes of the survey

The first layer involved a quantitative analyses of the perceptions of primary level teachers and science outreach practitioners in relation to constructivist learning environments. This analysis emanated from the results of the CLES survey. This analysis challenged beliefs that were presented in the literature about primary level teachers and science outreach practitioners. Primary level teachers have been accused for years of not being knowledgeable of, or implementing constructivist principles in their teaching and learning, which threatens science as a subject at primary level. Statements, like the one from Dr. Ed Walsh, former president of the University of Limerick, which called primary level a ‘disaster’ in terms of science teaching (Burke, 2008) and the large number of science education reports that criticise primary science teaching, emphasise this perception. For instance, Avraamidou (2013, p.1703) argues that there are “various related problematic issues with primary level teachers” in relation to the teaching of science. Also, Appleton (2007) argues that many primary level teachers have a limited understanding of the science content which they are required to teach and also lack pedagogical knowledge in science. In addition, Weiss et al. (2003) report that primary level teachers are not familiar with inquiry science and often avoid science because of their low levels of confidence in their own knowledge of the subject.

The analyses of the survey results was the first indication that this criticism of primary level teachers, visible in Burke (2008), Appleton (2007) and Weiss et al.’s (2003) literature is rather simplistic. The quantitative survey gave an insight into primary level teachers’ views of constructivist learning environments. The findings revealed that the participant teachers were favourable towards the five valued dimensions of constructivism, with shared control and student negotiation being the only two dimensions they were less convinced about, but nevertheless viewed as favourable. Furthermore, an identical survey applied to secondary science teachers, conducted by Savasci and Berlin (2012) yielded similar results. In this case, their least preferred dimensions were also uncertainty and shared control (Savasci and Berlin, 2012). Expert science teachers did not offer more constructivist perceptions than the primary level teachers in this research. Moreover, this study is the first, to the best of the researchers’ knowledge, to evaluate
Science outreach practitioners’ perceptions of constructivist learning environments. The survey also facilitated a comparison of views between science outreach practitioners’ perception of constructivist learning environments. By comparing outreach practitioners to teachers, it was possible to conclude that only one of the five dimensions of constructivism, namely personal relevance, was perceived more favourably by outreach practitioners than by teachers. In the other four, teachers had views that were significantly more biased towards the constructivist dimensions than the views of outreach practitioners, although the latter also favoured constructivist learning environments overall. Therefore, the results of this survey also challenge the view that science outreach is a remedy for a broken system of science education at primary level. This view is exemplified by Rushton et al. (2002, p. 7975). The authors developed a program for Massachusetts science teachers. Rushton et al. (2002) believe that these teachers are in need of assistance and outreach will provide it:

The primary intent of Tufts’ outreach program centered on introducing graduate-level engineering students as resources to assist classroom teachers in implementing activity and constructivist based engineering curricula.

The belief, that outreach practitioners develop constructivist practices that teachers do not have, has been identified as being based on vague justifications instead of hard facts (Bouville, 2008; Xie and Shauman, 2003). For the first time, outreach practitioners are compared with primary level teachers and the data reveals that assuming outreach practitioners are more disposed to develop constructivist practices than teachers is fallacious. In fact, primary level teachers revealed stronger tendencies towards constructivist perceptions than the outreach practitioners surveyed in this study.

Second layer: Outcomes of the quantification of interview data

The first layer of analyses, the analyses of the survey results, was the initial indicator that enabled the demystification of the notion that primary level teachers have problematic issues and that outreach is a corrector for primary level science. Nevertheless, the quantitative data from the survey was limited in its ability to explore the essence of this theory. The survey offered an indication of the overall preferences that primary level teachers and outreach practitioners have in relation to constructivist learning environments; yet “a survey cannot reveal the context […] which influences the respondents’ perceptions” (King, 1996, p. 174). Therefore, in order to reveal a truer sense of participants’ voices, an interview method was employed. To achieve this, the interviews were conducted with a different population of teachers and outreach practitioners, as negotiating access to interview revealed a different set of criteria to that of survey access. As such, it was realised that the same participants in many cases were not willing to undertake an additional, extended commitment. Participants had to be willing to give more of their time and willing to be more vulnerable in exposing their thoughts in a recorded, one-to-one conversation (Bloland et al., 1992). The interview engaged them in a dialectical analysis of conceptual and pedagogical dilemmas situated in a constructivist teaching scenario. Essentially, they were presented with two distinct scenarios and were asked to position themselves at either pole, or somewhere between. The rich qualitative data was analysed in two ways. First, because the participants positioned themselves in different places within the dilemmas (one extreme or somewhere within the binary), the qualitative data was quantified and the participants were identified along a Likert scale according to the description of their pedagogical choice. This quantification substantiated the results of the survey.
The participants that took part in the interview argued mostly for concepts and practices that gave more control to the student in the learning process or a mix between the two (rather than a leaning towards teacher control). And again, the only significant difference between teachers and outreach practitioners was the weight of the importance given to students controlling their own learning within the science lesson, with teachers giving it more weight. The quantification of the qualitative data further weakened the view of teachers as the problem that needed to be fixed by outreach.

Third layer: Qualitative outcomes of the interview, Outreach gatekeepers and hybrid practitioners

A third and fundamental layer of analysis was the qualitative analysis of the interview data. By presenting the participants with a binary choice, it engaged them in a dialectic reflection. It was this dialectic reflection that allowed exploration beyond the quantitative, ranking data and allowed one to unravel the tensions and contradictions faced by practitioners when having to make choices during their practice (Yoon and Kim, 2009). The qualitative analysis of the interview revealed the rich pedagogical knowledge of teachers, which strengthened the view obtained from the survey and the binary choices the teachers made in the interviews. The key outcomes are elaborated upon below.

Many of the voices of the participant teachers and some experienced science outreach officers revealed a rich and strong pedagogical knowledge, represented by the different strategies that were argued to promote student learning. Participants revealed that they are cognizant of multiple strategies advocated by constructivist education literature to foster student learning. They associated the role of interest in science with the need to contextualize learning in students’ realities demonstrating a sensibility to what Krapp and Prenzel (2011, p. 31) define as: “interest is associated with a pronounced readiness to acquire new domain-specific knowledge”. As well as being in line with Raizen and Michelsohn’s (1994) definition of an effective primary level teacher in science: “effective primary level teachers are aware of children’s ideas, prior knowledge and experience” (Koch, 2006, p. 25). Furthermore, several of the participants asserted that, to successfully promote students’ exploration, the process of reflection and the scaffolding of the teachers was fundamental. This represents what Davis (2006) and other scholars view as a key factor to facilitate the incorporation of inquiry in science teaching. Additionally, the participants also recognized kinaesthetic exploration and learning as a key teaching strategy, the need for “haptic experiences that prompt students to explore and manipulate objects and materials” (Jones et al., 2006, p.111). The active manipulation participants argued for, is a more efficient way for students to meaningfully learn science than more deductive practices (Glasson, 1989; Vesilind and Jones, 1996). Finally, some of the participants argued that exploration and learning of science is a collaborative enterprise, showing the social nature of constructivism as put by Gokhale (1995, p. 23): “students are capable of performing at higher intellectual levels when asked to work in collaborative situations than when asked to work individually”.

The extensive pedagogical knowledge that teachers demonstrated revealed a strong argument against the simplistic view that a lack of constructivist practice was at fault in terms of concerns about primary science education. This rich pedagogical knowledge and the constructivist perceptions that the survey and quantification of the interview data indicated does not align with literature findings as those described by Eivers and Clerkin, (2013, p. 78).

The 2009 National Assessments (Eivers et al., 2010) showed that Irish classrooms at second and sixth class levels are predominantly characterised by whole-class teaching and by pupils working by themselves (rather than in pairs or in small groups), as well as by the use of textbooks, reading schemes, and workbooks. These findings suggest
that constructivist teaching approaches in the classroom remain relatively rare compared to more “traditional” methods of instruction.

The dilemma-dialectical methodological approach helped to tease apart the contradiction and point to how teachers are indeed interrogating “their own beliefs and question institutional routines” (Windschitl, 2002, p.134). When the participant teachers and experienced outreach practitioners analysed dilemmas that depicted specific science classroom activities, they revealed tensions between the ideal, the pedagogical strategies they aim to develop, and the real classroom (as one participant described it, the chaotic classroom with thirty students). Participants engaged in a deductive-inductive dialectic immersion (Bencze and Bowen, 2009) and reflected upon their students and their context, and they couldn’t visualise some of the ideal pedagogical strategies working. Teachers argued issues of time, issues of curriculum and student age (in relation to their developing skill set). In previous studies, when teachers disclose these issues they are classified as having ‘transitional’ constructivist beliefs: “Classroom practices for this group of teachers are also beginning to align with reform, but the teacher still exhibits some traditional beliefs and/or practices” (Levitt, 2002, p.8). Through the dilemmatic reflection, it is possible to challenge the view that these teachers hold traditional beliefs. When many of the participants reflected on pedagogical approaches to teaching science, they recognized that the ones that give more control to the student are the best. Nevertheless, the participants highlighted the tensions and problems they would face in the classroom if they were to apply open inquiry practices. Indeed, they are not being ‘traditional’ as the literature suggests, but realistic about the demands of the chaotic classroom. And even in the educational literature itself it is possible to find support for the issues teachers face. As Fleer (2006, p.121) highlights, “No one really knows the best way to teach science to young children […] What is known is that the research base in science education has concentrated on children aged 8 years and older. What we have then is primary level teachers who are asked to develop science using teaching approaches that have been advanced and researched for older students”. Teachers are then accused of not having content knowledge, confidence and of holding negative attitudes towards science. Due to these perceived issues, outreach officers are tasked to bring more open ended pedagogies to the classroom, but experienced outreach officers also perceived similar issues. These experienced outreach officers are therefore hybrid practitioners. They reveal, as the teachers, a strong pedagogical knowledge and they also recognize the issues that teachers recognized. The participants’ reflections reveal that many teachers and outreach practitioners share the same view in relation to pedagogical strategies and issues relating to the complex reality of the classroom. Therefore, the view of outreach as a solution to primary science education is problematic.

Finally, the voices of the different practitioners (teachers and outreach practitioners) and the experience that the researcher had in carrying out outreach himself, uncovered the dynamics of the relationship between teachers and outreach providers. The understanding of this dynamic is crucial in the development of the third space, the “potential real space in which the informal sector can move, bridging the gap between school and community and hence blurring the boundaries between them” (Stocklmayer et al., 2010, p. 30). It was possible to identify two key dynamics: ad hocness and layers of access. The ad hocness is represented by the disparity between the frequencies of outreach amongst teachers of the same school. Some teachers were connected with the outreach providers. The classes of these ‘outreach connected’ teachers and the classes of their closest colleagues had coordinated outreach activities. At the same time, other teachers of the same school who did not have a connection with outreach or with the teachers who had, and as a result, did not have outreach in their classes. This resulted in outreach input being offered by chance, and so having less of an opportunity to be strategically applied to the primary classroom and as such impact students. The ‘outreach connected’ teachers can be seen as hybrid practitioners. They are at the same time teachers and promoters of outreach. These hybrid practitioners can play a crucial role in
creating the third space as they are experienced practitioners with a strong pedagogical knowledge and they recognize the issues that teachers face.

The second dynamic concerns layers of access. One layer, here defined as formal access is the one given by principals. From what outreach participants reported and the first-hand experience of the researcher, formal authorization given by principals was always necessary to develop outreach. Nevertheless, although the official authorization was given by the principals, the individual teachers had the final decision over whether or not they invited the outreach participant into their class. In many cases, this second layer of access (negotiation into the teachers’ classroom) was overcome with the assistance of outreach gatekeepers, who were experienced and respected teachers with connections to outreach and that advertised outreach to their colleagues. Furthermore, the outreach gatekeepers were, in many instances, the first point of contact, prior to engaging with the principal. Once teacher agreement was assured, this helped access at principal level. This suggests that the teachers were making decisions about the needs of their class, and the degree to which they needed support in their teaching. Therefore, as the data indicates, for the third space to work, it is crucial to understand that individual teachers have the keys to their classroom, and to recognize the dynamics of outreach gatekeepers and layers of access.

This third layer of analysis revealed the critical need to examine and carefully nurture the relationship between primary science teachers and outreach providers. The teacher is the most important stakeholder when it comes to planting the seed of science enjoyment in children. The literature recognises this, but in many cases assumes that the teachers are ignorant of science, getting in the way, or resisting reform. On the contrary, the primary level teachers that took part in this study revealed that they are well informed and that teachers and outreach providers are in agreement about the barriers to constructivist pedagogy. Therefore, the attention should shift away from teacher blame, or strategies to support the science-blind teacher, toward supporting the teacher-outreach symbiotic partnership. By supporting this partnership it is possible to create more hybrid practitioners that could play a crucial role in blurring the boundaries between formal and informal sectors in order to promote the enjoyment and engagement of students with science.

8.2 Implications and Recommendations

Policy-related, methodological and theoretical implications arise from this study. These are now described, starting with the theoretical implications.

This study developed an extensive review of the science outreach literature. Previous reviews have focused only on specific areas of outreach, such as outreach connected with engineering (Jeffers et al., 2004) or did not take into account recent developments (Crane et al., 1994). From a theoretical perspective both science outreach objectives and practices were reviewed. In terms of the variety of objectives that are listed in the literature there is a lack of categorization (Crane et al., 1994). As such this study developed a categorization model, identified in table 8.1, which organises science outreach objectives drawn from multiple and current outreach activities and domains, and classifies them into two distinct categories, educational and vocational, the two types of science outreach objectives first identified in Crane et al. (1994).
Furthermore, there was a lack of literature relating to the types of practices that science outreach embarks upon. The only review of practices that existed was limited to engineering outreach (Jeffers et al., 2004). One of the gaps identified in this study was a need for a stronger methodological basis for science outreach. Therefore a current overview of the multiple science outreach practices was warranted. This study of science outreach practices, by analysing science outreach reports, enhanced and modified the previous classification offered by the engineering-based study. It drew on the basic structure and adapted it to include a more complete depiction of research offered by the different science disciplines that conduct science outreach, as seen in table 8.2. One more category of outreach practice was added, cooperative projects, to reflect collaborations between scientists and students in actual science work.

Table 8.1 Educational and vocational objectives of outreach, modified from Crane et al. (1994)

<table>
<thead>
<tr>
<th>Objectives of Science Outreach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Educational Objectives</td>
</tr>
<tr>
<td>Experience</td>
</tr>
<tr>
<td>Performance</td>
</tr>
<tr>
<td>Literacy</td>
</tr>
<tr>
<td>Vocational objectives</td>
</tr>
<tr>
<td>Love of Science</td>
</tr>
<tr>
<td>Confidence that one can do Science</td>
</tr>
<tr>
<td>Progress towards a career in Science</td>
</tr>
<tr>
<td>Equality in Science</td>
</tr>
</tbody>
</table>

Furthermore, there was a lack of literature relating to the types of practices that science outreach embarks upon. The only review of practices that existed was limited to engineering outreach (Jeffers et al., 2004). One of the gaps identified in this study was a need for a stronger methodological basis for science outreach. Therefore a current overview of the multiple science outreach practices was warranted. This study of science outreach practices, by analysing science outreach reports, enhanced and modified the previous classification offered by the engineering-based study. It drew on the basic structure and adapted it to include a more complete depiction of research offered by the different science disciplines that conduct science outreach, as seen in table 8.2. One more category of outreach practice was added, cooperative projects, to reflect collaborations between scientists and students in actual science work.

Table 8.2 Practices of science outreach, modified from Jeffers et al. (2004).

<table>
<thead>
<tr>
<th>Practices of Science Outreach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Develop classroom material including Web-based resources</td>
</tr>
<tr>
<td>Conduct outreach activities on the college campus</td>
</tr>
<tr>
<td>Conduct outreach activities at the K-12 school</td>
</tr>
<tr>
<td>Conduct or sponsor science contests</td>
</tr>
<tr>
<td>Cooperative projects</td>
</tr>
<tr>
<td>Teacher involvement</td>
</tr>
</tbody>
</table>

This thesis also facilitated the dialectical analysis of science education learning models according to the dichotomies autonomy/dependency, induction/deduction and creativity/guidance. The science education models were presented within the dichotomies that this study developed to illustrate a pedagogical application of each of these dichotomies. This application is particularly relevant as reform in science education and outreach is grounded in principles of constructivism. Therefore it was important to understand how the different models that are used in science education are positioned according to the relevant dichotomies.

Methodologically, this study contributed for the first time (as evident from the lack of literature available), to the comparison between outreach practitioners and primary level teachers in relation to their perceptions of constructivist teaching and learning strategies. Furthermore, this study gave
voice for the first time to science outreach practitioners in relation to their opinions of conceptual and pedagogical dilemmas. From a methodological perspective, this research involved the design of an innovative qualitative methodology, designed to actively engage teachers and outreach practitioners in a dialectical discussion about their teaching and learning methodologies. The purpose of the dialectical discussion was to confront participants with opposing arguments that innately challenge them into an inductive-deductive dialectic immersion. In order to support this scenario, a series of animated videos were designed, created and piloted, that presented each dichotomy in a classroom situation, contextualised in activities chosen from the primary science curriculum (pedagogical dichotomies) and informal teacher discussions (conceptual dichotomies). These video cases could be applied to a wider study, internationally, or the methodology itself could be applied to other education-based topics that warrant discussion.

In terms of policy implications, the findings of the current study draw implications for science teaching at primary level. One of the main findings was that teachers, when presented with specific science activities, recognize the issues and problems they face in the complex reality of the classroom. In other jurisdictions such as the UK or Portugal, two types of solution have been offered to support classroom reality when teaching science. For instance, in Portugal, starting with students from the age of 10, science classes are divided in two groups. In one day half of the class has science while the other half is with another teacher (Ramalho, 2007). This type of solution allows the teacher to develop practical inquiry activities with half of the students at a time, which facilitates the role of teacher in the management of the class (Ramalho, 2007). Another solution that has been used for the science lessons is to have an assistant to help with the activities in the classroom (Horlock, 2002). Either of the strategies can be fruitful in facilitating teachers’ opportunities to develop more constructivist practices in science (Ramalho, 2007; Horlock, 2002).

Furthermore, policy wise, previous reports have assumed that primary level teachers did not have strong pedagogical sense, and were resistant to constructivist approaches. Specifically in the inquiry learning literature, the recurrent view that teachers lack pedagogical content knowledge to develop inquiry practices exists and that changes to incorporate new practices “will likely to be impeded by classroom tradition and practice” (Stocklmayer at al.,2011, p.7 ). However, this study suggests that, for the participant primary level teachers, this was not the case. Therefore if primary teachers’ professional ability is recognized, it may change the current approach of outsiders coming in to promote science in primary school. The third space will then not be one in which outreach brings the ‘good science’ in a way that resembles the deficit model (Wynne, 1989). If the mindset moves away from ‘bad teacher’ to one that sees teachers as equal stakeholders with outreach providers, it will strengthen the ability to promote science by ensuring that the teacher-outreach dyad is carefully understood and supported. It can promote a symbiotic partnership.

The findings of this research may also have policy implications for outreach professional development workshops. The workshops that exist tend to focus on how to develop inquiry learning activities (Thiry et al., 2008). The findings from the interviews revealed that outreach practitioners are predisposed to open inquiry activities. It was only when discussing and exploring conceptual underpinnings of constructivism such as autonomy of the student and the role of creativity, that outreach practitioners had more concerns. Therefore, outreach professional development workshops should provide an opportunity for scientists to reflect on such concepts.

Moreover, this research also revealed an important gatekeeper dynamic in outreach that may be of relevance. There are already initiatives established, such as the ISOTOPE (Europe) or the STEM Outreach Resource database (USA), which aim to facilitate the relationship between outreach and the public (Holliman et al., 2009; Brown, 2015). Both projects have a published list of the outreach practitioner members, with their location and forthcoming activities. The main objective of these databases is to assist scientists and other stakeholders in bringing outreach to the public and limit the constraints they suffer (Holliman et al., 2009; Brown, 2015). This objective could be better
fulfilled if these databases also took advantage of outreach gatekeepers and hybrid practitioners, which are teachers that promote science in their schools and that have experience and connections with outreach. These databases could identify willing outreach gatekeepers from different schools and/or regions as they do already with outreach practitioners. These databases could function as professional networks designed to mobilise the dual expertise from both stakeholder groups. They would then function as a bridge that could facilitate the coordination and effectiveness of outreach practices in schools.

8.3 Recommendations for future research

The recommendations for future research are categorised within the realms of theory, methodology and policy.

Theoretically, this study reviewed science education models of teaching and learning as applied to a dialectic, constructivist dichotomy. The models reviewed are those that fall into the information processing models framework. Nevertheless, other models of teaching and learning, such as mastery learning are now being adapted to science education programmes (Zimmerman, 2008). Further research could examine these teaching and learning models according to dialectic constructivist dichotomies. Studying other models of teaching and learning according to constructivist dichotomies can broaden the diversity of constructivist pedagogical practices beyond the gold standard inquiry learning.

Methodologically, this study developed video-cases around relevant concepts and activities to promote the dialectical reflection of teachers and outreach practitioners. They were built with the input of teachers and outreach practitioners to accentuate their authenticity. However, other dichotomies could also be relevant to teachers and outreach practitioners. Consequently, future research could analyse, adapt and modify these video-cases in order to use them in other contexts. The novel qualitative instrument allowed for teaching agency, to reveal the potential to produce rich data, and for dialectical reasoning (deductive/inductive) of the research participants.

Finally, this study focused on the perceptions and reflections of teachers and science outreach practitioners. Nonetheless, upstream actors, such as policymakers and politicians also influence science education and outreach. Future research could incorporate the views of other actors in the issues this study covered. By incorporating views of upstream actors, the potential to promote symbiotic partnerships as well as the promotion of hybrid pedagogical practitioners can be explored. These views can finally explore the possibility of developing regular strategy networks for science engagement.
Appendix A
Autonomy/Dependency

Setting: Teachers room. One teacher is seated reading something in the laptop. A second teacher enters the room. The first teacher looks in the direction of the second teacher.

Teacher 1: Hi,
Teacher 2: Hi, what are you reading there?
Teacher 1: I’m reading two texts on how to teach the kids, they are saying the complete opposite. It just left me confused.
Teacher 2: Ok.
Teacher 1: Have a look: In this one, they’re saying students should have control of their own learning and we should build new learning from what they know. They argue that for that to happen we should give them enough time for them to make sense of new learning and experiences.
Teacher 2: Ok,
Teacher 1: Yeah, but this second one also makes a lot of sense. They are saying that we have a curriculum we need to teach the students. They need to finish the primary level understanding some science aspects, and this restricts the autonomy of the students to go into areas that interest them, it restricts the time we have!
Teacher 1: Hmm, Hmm.
Teacher 2: So, what do you think, with which one do you agree more with?

Link for the video: https://www.dropbox.com/s/rxn3dbqz19h92fp/video%201.avi?dl=0
Induction/Deduction

Setting: Teachers room. One teacher is seated reading a piece of paper. A second teacher enters the room. The first teacher looks in the direction of the second teacher.
Teacher 1: Hey, what are you doing?
Teacher 2: Hello, I'm reading two texts regarding how to conduct a lesson and I'm in doubt of which one to follow.
Teacher 1: Ok, so what do they say?
Teacher 2: So, the first argues that we should start by giving the kids facts, data and let them form an idea about what they are seeing. They should first examine the data and form a generalized idea about their observations.
Teacher 1: Ok.
Teacher 2: The thing is that, in this second article the author argues the complete opposite, she says that we should give direct instructional guidance to the students and not let them discover by themselves. First, we should explain the concepts they need to learn and only after give examples. What do you think?

Link for the video: https://www.dropbox.com/s/ho0uysygjef3hcc/video%202.avi?dl=0
Setting: Teachers room. One teacher is seated reading something in the laptop. A second teacher enters the room. The first teacher looks in the direction of the second teacher.
Teacher 1: Hey, what are you doing?
Teacher 2: Hello, I'm reading two texts about creativity.
Teacher 1: Ok.
Teacher 2: Yeah, The first one says we should teach science in a way to promote creativity. They argue that creativity involves the ability to offer new perspectives, generate new ideas, and raise new questions. So, they say that we need to reward and encourage new ideas and perspectives in our class.
Teacher 1: Hmm hmm.
Teacher 2: But, this other article is stating that in science, creativity is secondary and is a distraction from the purpose of the lesson; like the example they give of this teacher, who says that the way he guarantees their students success in science is by having them take a particular approach to solving problems, a structured approach. In the solving of problems, this teacher wants that the students follow a set procedure, and have a successful model of problem solving. What do you think?

Link for the video: [https://www.dropbox.com/s/j8upx9rzquwam2y/video%203.avi?dl=0](https://www.dropbox.com/s/j8upx9rzquwam2y/video%203.avi?dl=0)
Appendix B
Original Activity (DPS, 2012)

Flower Power
Botanical Activity

Question: What happens if you put a flower in a cup of coloured water?
What is your group’s hypothesis (a guess for the answer to this question)?

Materials you will need:
• Some water
• 25 drops of Red Food colouring
• 1 Jam jar
• 1 white flower

Now conduct your experiment! Here are the steps:
1. Fill the glass jar with 2cm of water.
2. Add 25 drops of food colouring.
3. Put the flower in the water
4. Wait for 10 to 12 minutes, while looking very closely at your flower.

Question: What has happened? (Hint, look very closely at the petals and the stamen (the bits in the middle of the flower). Record your findings here

Question: So, what is your conclusion? (You will have a class discussion and your teacher will help you with this part).

Adaptation

Open Inquiry

Setting: Classroom organized with tables divided in different groups. Teacher is facing the students.

Teacher: Hi Class. Today we are investigating how water influences plant growth. We have, for this experiment, coloured water and a white flower. First, I would like you to think about what questions we can ask from using coloured water in a plant. After that, I want you to try to answer your questions by doing an experiment. These are the materials I have for you today. With these materials try to design the experiment. After you design it, do it! Observe what happens and answer your question. I’ll be here the whole time and I’ll help you throughout it.

Structured inquiry

Setting: Classroom organized with tables divided in different groups. Teacher is facing the students.
Teacher: Hi Class. Today we are investigating the following question: What happens if you put a flower in a cup of coloured water?

The material you need is in your tables. Here is the worksheet with the detailed steps of the experiment. When conducting the experiment write down your observations. Afterwards we’ll have a classroom discussion in which we’ll discuss your observations.

Link for the videos: https://www.dropbox.com/s/4orcq3govmg3p4/video%204a.avi?dl=0
https://www.dropbox.com/s/e8rqayp9wyi90az/video%204b.avi?dl=0
Appendix C
Original Activity (DPS, 2012)

Teacher: Hi Class. Today we will be making a magnetic car and by playing with it you’ll understand how magnets work. In this activity you will make the matchbox cars with the wheels and axes. Try and understand how magnets work and make the cars move with them. In the end of this activity we’ll have a classroom discussion to compare your conclusions about how magnets work.

Deductive activity
Setting: Classroom organized with tables divided in different groups. Teacher is facing the students.

Teacher: Hi Class. Today we will understand how magnets work. You will be using this information then, to make and play with a magnetic car. Here is some important information. You can get the car to move without touching it. Two magnets can either attract or repel each other. If the North pole of the magnet in the car is facing the North pole of the other magnet, the magnets will repel each other and the car will move. Similarly with the South poles facing each other. Now, make the matchbox cars with the wheels and axles. Get them to move using the repelling forces between the like poles of two magnets. You can then observe how magnets work.

Link for the videos: https://www.dropbox.com/s/wbvuwle7xlxyl6/video%205a.avi?dl=0
https://www.dropbox.com/s/jp7mmgevq17mk0j/video%205b.avi?dl=0
Appendix D
Original Activity (DPS, 2012)

Adaptation

**Student led construction**

Teacher: Today we’ll be designing a toy using the principle of a lever. When you push or pull one part of a lever, you make it push or pull on another part in the opposite direction. A lever is a simple machine consisting of a rigid bar that can turn about something called a pivot. Levers can be used to lift heavy weights or change the direction of a force (e.g., you sit on one end of a seesaw and the other end goes up; you press down on a screwdriver and the lid comes up). You can make toys which operate on this principle. So now, you have the materials and instructions to make a lever, try and design a toy of your choice, using the lever and the rest of the materials you have on the table.

**Teacher led construction**

Setting: Classroom organized with tables divided in different groups. Teacher is facing the students.
Teacher: Today we’ll be designing a toy using the principle of a lever. When you push or pull one part of a lever you make it push or pull on another part in the opposite direction. A lever is a simple machine consisting of a rigid bar that can turn about something called a pivot. Levers can be used to lift heavy weights or change the direction of a force (e.g. you sit on one end of a seesaw and the other end goes up; you press down on a screwdriver and the lid comes up). You can make toys which operate on this principle. So now, using the materials and instructions, you have to design WAG, a dog which sticks out its tongue when you wag its tail.

Link for the videos: https://www.dropbox.com/s/l7btko4be6izctaa/video%206a.avi?dl=0
https://www.dropbox.com/s/7f2izlndmuj2cn/video%206b.avi?dl=0
Appendix E
INTERVIEW GUIDE

Introduction to the interview:

Good morning. Thank you for having the time to meet with me and for signing the consent form agreeing to this interview. Please let me know if you still have some questions. As I mentioned in the invitation letter, today I will be presenting to you six short videos, less than two minutes long. They portray conversations between teachers and classroom situations. These videos use animation to explain the situations. First of all, I would like to ask you if I can audiotape this interview.

Second we would start with some short demographic and background questions.
- School level you teach?
- Gender?
- For how many years do you teach in the primary level?
- Have you ever had science outreach initiatives in your classroom?

Version for outreach
- Role in the University and area of outreach?
- Gender?

I will now present the first video:

**Script for the first video (in the DVD)**

Question 1.1: From the two opinions presented in the quotes, which one do you agree more?
Question 1.2: Could you explain me why did you choose that opinion?
(Probing and questions to further explain research participants opinion will follow)
Question 1.3: Could you mark in the following line the relative position of your opinion between the 2 quotes

We will now pass to the second video

**Script for the Second video (in the DVD)**

Question 2.1: From the two opinions presented in the quotes, which one do you agree more?
Question 2.2: Could you explain me why did you choose that opinion?
(Probing and questions to further explain research participants opinion will follow)
Final question: Could you mark in the following line the relative position of your opinion between the 2 quotes

We will now pass to the third video:

**Script for the Third video (in the DVD)**

Question 3.1: From the two opinions presented in the quotes, which one do you agree more?
Question 3.2: Could you explain me why did you choose that opinion?
(Probing and questions to further explain research participants opinion will follow)
Question 3.3: Could you mark in the following line the relative position of your opinion between the 2 quotes

Thank you. Now we are going to pass to the 3 videos that show a teacher presenting activities to the students. Each video has two ways of performing the same activity.

**Script for Video 4 (in the DVD)**

Question 4.1: Between these two options to conduct this activity, which one do you agree more with?
Question 4.2: Could you explain me why did you choose that opinion?
(Probing and questions to further explain research participants opinion will follow)

We will now pass to the next video.

**Script for Video 5 (in the DVD)**

Question 5.1: Between these two options to conduct this activity, which one do you agree more with?
Question 5.2: Could you explain me why did you choose that opinion?
(Probing and questions to further explain research participants opinion will follow)
We will now pass to the last video.

**Script for Video 6 (in the dvd)**

Question 6.1: Between these two options to conduct this activity, which one do you agree more with?

Question 6.2: Could you explain me why did you choose that opinion?
(Probing and questions to further explain research participants opinion will follow)

Would you like to add something?

Thank you for your collaboration.
1) Please indicate that you read the information in the invitation email and understand the following:

[ ] That I am free to withdraw at any time
[ ] That all information I provide will be dealt with in a confidential manner

2) Are you a:*

[ ] Graduate student
[ ] Science Outreach Officer
[ ] Post Doctoral Researcher
[ ] Lecturer
[ ] Senior lecturer
[ ] Professor

3) Gender

[ ] Male
[ ] Female

4) How often do you do science outreach initiatives?

[ ] a. Every week
[ ] b. Less than once a week but more than once a month
[ ] c. Once a month
[ ] d. Less than once a month but more than once a year
[ ] e. Once a year
[ ] f. Less than once a year
[ ] g. Never did one
5) In outreach initiatives . . .
Students learn about the world outside of school.

( ) A Almost Always  ( ) B Often  ( ) C Sometimes  ( ) D Seldom  ( ) E Almost Never

6) In outreach initiatives . . .
New learning relates to experiences or questions about the world inside and outside of school.

( ) A Almost Always  ( ) B Often  ( ) C Sometimes  ( ) D Seldom  ( ) E Almost Never

7) In outreach initiatives . . .
Students learn how science is a part of their inside- and outside-of-school lives.

( ) A Almost Always  ( ) B Often  ( ) C Sometimes  ( ) D Seldom  ( ) E Almost Never

8) In outreach initiatives . . .
Students learn interesting things about the world inside and outside of school.

( ) A Almost Always  ( ) B Often  ( ) C Sometimes  ( ) D Seldom  ( ) E Almost Never

9) In outreach initiatives . . .
Students learn that science cannot always provide answers to problems

( ) A Almost Always  ( ) B Often  ( ) C Sometimes  ( ) D Seldom  ( ) E Almost Never

10) In outreach initiatives . . .
Students learn that scientific explanations have changed over time

( ) A Almost Always  ( ) B Often  ( ) C Sometimes  ( ) D Seldom  ( ) E Almost Never

11) In outreach initiatives . . .
Students learn that science is influenced by people's cultural values and opinions.

( ) A Almost Always  ( ) B Often  ( ) C Sometimes  ( ) D Seldom  ( ) E Almost Never
12) In outreach initiatives . . .
Students learn that science is a way to raise questions and seek answers.

( ) A Almost Always  ( ) B Often  ( ) C Sometimes  ( ) D Seldom  ( ) E Almost Never

13) In outreach initiatives . . .
Students feel safe questioning what or how they are being taught.

( ) A Almost Always  ( ) B Often  ( ) C Sometimes  ( ) D Seldom  ( ) E Almost Never

14) In outreach initiatives . . .
I feel students learn better when they are allowed to question what or how they are being taught.

( ) A Almost Always  ( ) B Often  ( ) C Sometimes  ( ) D Seldom  ( ) E Almost Never

15) In outreach initiatives . . .
It's acceptable for students to ask for clarification about activities that are confusing.

( ) A Almost Always  ( ) B Often  ( ) C Sometimes  ( ) D Seldom  ( ) E Almost Never

16) In outreach initiatives . . .
It's acceptable for students to express concern about anything that gets in the way of their learning.

( ) A Almost Always  ( ) B Often  ( ) C Sometimes  ( ) D Seldom  ( ) E Almost Never

17) In my outreach initiatives . . .
Students help me plan the activities they will be doing.

( ) A Almost Always  ( ) B Often  ( ) C Sometimes  ( ) D Seldom  ( ) E Almost Never
18) In my outreach initiatives . . .
Students help me to decide which activities work best for them
( ) A Almost Always  ( ) B Often  ( ) C Sometimes  ( ) D Seldom  ( ) E Almost Never

19) In outreach initiatives . . .
Students let me know if they need more/less time to complete an activity
( ) A Almost Always  ( ) B Often  ( ) C Sometimes  ( ) D Seldom  ( ) E Almost Never

20) In outreach initiatives . . .
Students talk with other students about how to solve problems.
( ) A Almost Always  ( ) B Often  ( ) C Sometimes  ( ) D Seldom  ( ) E Almost Never

21) In outreach initiatives...
Students explain their ideas to other students.
( ) A Almost Always  ( ) B Often  ( ) C Sometimes  ( ) D Seldom  ( ) E Almost Never

22) In outreach initiatives...
Students ask other students to explain their ideas
( ) A Almost Always  ( ) B Often  ( ) C Sometimes  ( ) D Seldom  ( ) E Almost Never

23) In outreach initiatives...
Students are asked by others to explain their ideas
( ) A Almost Always  ( ) B Often  ( ) C Sometimes  ( ) D Seldom  ( ) E Almost Never

24) If you would like to be in the chance to win a Kindle please indicate your email.

_________________________________________________
Thank You!
1) Please indicate that you read the information in the invitation email and understand the following:
[ ] That I am free to withdraw at any time
[ ] That all information I provide will be dealt with in a confidential manner

2) Gender
[ ] Male
[ ] Female

3) Have you ever had science outreach initiatives (eg. a guest in the classroom doing science activities) in your school?
[ ] Yes
[ ] No

4) Please indicate how many students does your school have?
   ( ) a. less than 180 students
   ( ) b. more than 180 students

5) In my classroom . . .
Students learn about the world of science outside of school.
   ( ) A Almost Always    ( ) B Often    ( ) C Sometimes    ( ) D Seldom    ( ) E Almost Never

6) In my classroom . . .
New learning builds on experiences or questions about the world inside and outside of school.
   ( ) A Almost Always    ( ) B Often    ( ) C Sometimes    ( ) D Seldom    ( ) E Almost Never
7) In my classroom . . .
Students learn how science is a part of their inside- and outside-of-school lives.

( ) A Almost Always    ( ) B Often    ( ) C Sometimes    ( ) D Seldom    ( ) E Almost Never

8) In my classroom . . .
Students learn interesting things about the world inside and outside of school.

( ) A Almost Always    ( ) B Often    ( ) C Sometimes    ( ) D Seldom    ( ) E Almost Never

9) In my classroom . . .
Students learn that science cannot always provide answers to problems

( ) A Almost Always    ( ) B Often    ( ) C Sometimes    ( ) D Seldom    ( ) E Almost Never

10) In my classroom . . .
Students learn that scientific explanations have changed over time

( ) A Almost Always    ( ) B Often    ( ) C Sometimes    ( ) D Seldom    ( ) E Almost Never

11) In my classroom . . .
Students learn that science is influenced by people's cultural values and opinions.

( ) A Almost Always    ( ) B Often    ( ) C Sometimes    ( ) D Seldom    ( ) E Almost Never

12) In my classroom . . .
Students learn that science is a way to raise questions and seek answers

( ) A Almost Always    ( ) B Often    ( ) C Sometimes    ( ) D Seldom    ( ) E Almost Never

13) In my classroom . . .
Students feel safe questioning what or how they are being taught.

( ) A Almost Always    ( ) B Often    ( ) C Sometimes    ( ) D Seldom    ( ) E Almost Never
14) In my classroom . . .
I feel students learn better when they are allowed to question what or how they are being taught.

( ) A Almost Always  ( ) B Often  ( ) C Sometimes  ( ) D Seldom  ( ) E Almost Never

15) In my classroom. . .
It’s acceptable for students to ask for clarification about activities that are confusing.

( ) A Almost Always  ( ) B Often  ( ) C Sometimes  ( ) D Seldom  ( ) E Almost Never

16) In my classroom . . .
It’s acceptable for students to express concern about anything that gets in the way of their learning.

( ) A Almost Always  ( ) B Often  ( ) C Sometimes  ( ) D Seldom  ( ) E Almost Never

17) In my classroom . . .
Students help me plan the activities they will be doing.

( ) A Almost Always  ( ) B Often  ( ) C Sometimes  ( ) D Seldom  ( ) E Almost Never

18) In my outreach classroom. . .
Students help me to decide which activities work best for them

( ) A Almost Always  ( ) B Often  ( ) C Sometimes  ( ) D Seldom  ( ) E Almost Never

19) In my classroom . . .
Students let me know if they need more/less time to complete an activity

( ) A Almost Always  ( ) B Often  ( ) C Sometimes  ( ) D Seldom  ( ) E Almost Never

20) In my classroom . . .
Students talk with other students about how to solve problems.
21) In my classroom...
Students explain their ideas to other students.

( ) A Almost Always  ( ) B Often  ( ) C Sometimes  ( ) D Seldom  ( ) E Almost Never

22) In my classroom...
Students ask other students to explain their ideas

( ) A Almost Always  ( ) B Often  ( ) C Sometimes  ( ) D Seldom  ( ) E Almost Never

23) In my classroom...
Students are asked by others to explain their ideas

( ) A Almost Always  ( ) B Often  ( ) C Sometimes  ( ) D Seldom  ( ) E Almost Never

24) If you would like to be in the chance to win a Kindle please indicate your email
__________________________________________________________

Thank You!
Appendix G
NUIG Science Education/Outreach 2 minutes survey. Chance to win a Kindle!

Dear Dr Trent,

We are currently conducting a survey regarding how science learning environments are perceived by scientists. This investigation is organized through the School of Education of the National University of Ireland, Galway. The survey only takes 2 minutes and is available in the link below. We would be very grateful if you would complete it:


To encourage your participation, there are 2 Kindles to be won!

In terms of impact, we hope that the results of this survey will effect policy decisions in terms of quantifying and identifying the necessity for additional resources in science education at primary level. Furthermore, contribution to this study will enable us to clarify what role science outreach (by neighbouring science facilities/colleges) can play in terms of supporting a more engaging science experience for primary level students.

The survey will be accessible until November 8. You will be sent an email reminder close to this date.

If you have any questions or comments relating to this research, I would be happy to answer them via phone or email (085 2395168 or d.martinsgomes1@nuigalway.ie). Alternatively, please contact Dr. Veronica McCauley, from the School of Education, at the National University of Ireland, Galway (091 495260 or veronica.mccauley@nuigalway.ie).

Thank you in advance for your valuable contribution to this research.

Kindest Regards,
NUIG Science Education/Outreach 2 minutes survey.
Chance to win a Kindle!

Dear Principal,

I am writing from the School of Education, NUI Galway. We are currently conducting a national survey that explores teachers’ views on how science education should be taught at primary level. The survey will only take 2 minutes and is available in the link below. We would be very grateful if you would complete it and forward it to your teaching staff:


In addition to all participants receiving a summary of the overall key findings of this investigation, for every survey completed we will donate 20 cents to Our Lady’s Children’s Hospital, Crumlin. Also, to encourage your participation, there are 2 Kindles to be won!

In terms of impact, we hope that the results of this survey will effect policy decisions in terms of quantifying and identifying the necessity for additional resources in science education at primary level. Furthermore, contribution to this study will enable us to clarify what role science outreach (by neighbouring science facilities/colleges) can play in terms of supporting a more engaging science experience for primary level students.

The survey will be accessible until October 30. you will be sent an email reminder close to this date.

If you have any questions or comments relating to this research, I would be happy to answer them via phone or email (085 2395168 or d.martinsgomes1@nuigalway.ie). Alternatively please contact Dr. Veronica McCauley, from the School of Education, at the National University of Ireland, Galway (091 495260 or veronica.mccauley@nuigalway.ie).

Thank you in advance for your valuable contribution to this research

Kindest Regards,
Appendix H
Sent on behalf of Dr Brian McGuiré, Research Ethics Committee

Re: Ethics Application: Science Outreach and Science Education on the Primary Level: A Mixed Methods Study

I write to you regarding the above proposal which was submitted for Ethical review. Having reviewed your response to my letter, I am pleased to inform you that your proposal has been granted APPROVAL.

All NUI Galway Research Ethics Committee approval is subject to the Principal Investigator submitting an annual report to the Committee. The first report is due on or before 30th September 2013. Please see section 7 of the REC's Standard Operating Procedures for further details which also includes other instances where you are required to report to the REC.

Yours Sincerely

Brian McGuiré
Research Ethics Committee
Appendix I
Science Outreach in the Primary Classroom

Research Participants Invitation and Information Sheet

Study Title: Science Outreach and Science Education in the Primary Level: A Mixed Methods Study. 
Researcher: Diogo Gomes

Invitation Paragraph
You are being invited to take part in a research study. Before you decide, it is important for you to understand why this research is being carried out and what it will involve. If you agree to take part, you will be asked to sign a Consent Form. If there is anything that you are not clear about, I will be happy to explain it to you. Please take as much time as you need to read this information form. You should only consent to participate when you feel that you understand what is being asked of you, and you have had enough time to think about your decision.

Thank you for reading this.

What is the purpose of the study?
This study is looking into how initiatives of science promotion offered by universities to primary level schools can assist science education at primary level. Particularly we are interested in understanding how teachers and science outreach officers choose and develop science activities. We propose to identify how science outreach can then position itself better in primary level education. We invited you to participate because you are a primary level teacher/science outreach practitioner.

Do I have to take part?
We hope that you will consider taking part. If you decide to take part you are still free to withdraw at any time and without giving a reason.

What will I do if I take part?
If you are happy to participate in the research please sign the consent form. You will then be asked some interview questions in reference to some teaching scenarios presented in a video format.

How long will my part in the study last?
The interview should not take more than 30 minutes.

What do I have to do?
We will ask you to give your opinion about the teaching methods used and discussed in the animated video clips which are related to teaching science in the primary classroom.
What are the possible disadvantages or risks in taking part?

Whilst you will be asked to answer questions, all information provided by you will be kept confidential at all times. All responses to our questions and information provided by you will be anonymised i.e. no personal details relating to you or where you work will be recorded anywhere. Only members of the research team will have access to the information you provide us.

What are the possible benefits of taking part?

This interview is designed to offer an opportunity to reflect about issues faced in practice, in particular in relation to teaching science. You may find this to be a beneficial experience. Ultimately this study aims to contribute to the partnerships between science education at primary level and science outreach activities offered by external partners (e.g. universities).

What will happen to the results of the research study? All information provided by you will be stored anonymously on a computer with analysis of the information obtained undertaken by the research team based at National University of Ireland, Galway (NUIG). The results from this analysis will be available in one or more of the following sources; scientific papers in peer reviewed academic journals; presentations at a regional conference; local seminars. The findings will be available through the research team.

Who is organizing the research?

The research Project is part of a PhD being undertaken in the School of Education, NUIG.

What happens if I change my mind during the study?

You can change your mind about participation at any time during the course of the study without disadvantage or penalty to yourself.

What if I have a complaint during my participation in the study?

If you have any complaints during the study please tell the researcher directly during the interview process or afterwards by email. You also have the option of contacting an independent party within NUI Galway. Contact details are given below.

Whom do I contact for more information or if I have further concerns?

You may contact the PhD candidate responsible for the research:
Diogo Gomes,
Email: d.martinsgomes1@nuigalway.ie

or

If you have any concerns about this study and wish to contact someone independent and in confidence; you may contact the Chairperson of the NU! Galway Research Ethics Committee, c/o Office of the Vice President for Research, NUI Galway, ethics@nuigalway.ie
Title: Science Outreach in the Primary Classroom.

Participant Consent Form

I wish to participate in the above named project.

I have read the participant information sheet for the above research project and understand the following:

1. That I am free to withdraw at any time. ___
2. That all information I provide will be dealt with in a confidential manner. ___
3. I agree that the researcher may contact me. ___

Signed…………………………………………………………………………………………

Address……………………………………………………………………………………

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Email……………………………………………………………………

Date…………………………………………………………………………………………
Appendix J
Dichotomy 1a: Autonomy/Dependency

The premise of this Autonomy/Dependency conceptual dichotomy is: the importance of the students having control of their own learning within the science lesson VS. teachers taking a more complete role in controlling student learning.

<table>
<thead>
<tr>
<th>Autonomy (1)</th>
<th>More autonomy than dependency (2)</th>
<th>A mix between the two (3)</th>
<th>More dependency than autonomy (4)</th>
<th>Dependency (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The first. I think people should have freedom in the science curriculum. I think in the primary school in Ireland there is the freedom to when you see that something has gained their interest to let them do a project or whatever, so I definitely would go with the first one.</td>
<td>I agree more with the first one that you start from the child’s learning point and their interest because if they are interested they will do a lot of the learning themselves as opposed to being taught. Of course you do have to give the input from the teacher, input has to be there. We have to make sure that they get a balanced curriculum that they get some from each of the strands and the strand units.</td>
<td>In my class I combine the two. So we’re doing electricity in the class now so I today let them blow up balloons and get the static electricity themselves so they could see actually see how electricity works and then they have to find electricity at home, so I suppose I combine what’s in the curriculum with what they want make it fun and let the children discover like they’re the scientists. I try to combine the two.</td>
<td>At this age group I’d agree more with the second one, more structured. I’ll actually be half way between the two, a grey area between the two, to be honest. I think specially in science there’ll be a lot of don’ts. I think you do have to direct their learning , but, as well just if you could allow them to, say if you do something with water, you could let them play with the water and explore the materials on their own.</td>
<td>Definitely time constrain in here, by the time you get your core subjects, your English, Irish, maths that takes an awful lot of time, and as well, when they go into group learning, giving them time to their own kind of research, at this age, they are very difficult, a lot more work has to be put in to cooperative learning, or working in groups and the ability of the kids would be a big factor. At this age no, it would be more teacher led.</td>
</tr>
</tbody>
</table>

Dichotomy 1b: Open/Guided Inquiry

The premise of this Open/Guided Inquiry pedagogical dichotomy is: students investigate how water influences plant growth. The students are only given the materials (flower and cup of coloured water), they think about what questions can be asked with the materials they have, they design the experience themselves, and carry it out VS. The students investigate a specific question given by the teacher: What happens if you put a flower in a cup of coloured water? The teacher gives the students the detailed worksheet with the steps of the experiment and asks them to conduct it.

<table>
<thead>
<tr>
<th>Open inquiry (1)</th>
<th>More open than guided inquiry (2)</th>
<th>A mix between the two (3)</th>
<th>More guided than open inquiry (4)</th>
<th>Guided inquiry (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Definitely the first one. Because it gets them thinking as well, do for themselves and they actually figuring out how should they experiment themselves, and the teacher being there as a facilitator.</td>
<td>I think the first where she gave them everything and she allowed them to do it she didn’t give them the instructions and lead them how to do it. I think that would be the one that I would probably start with and then I go around and helped them like. I probably start with one and then I’d write up the experiment together so they would work in groups to do the experiment, yah, I don’t think I would give them the instructions straight way, because that’s done for them, again I think it really depends on class level.</td>
<td>Ideally you would be using the first one where you’re getting them to come up with it themselves, this level I wouldn’t give as much detail as the second one. I think she was doing everything, it was all there, they’re not really having to think they just have to make sure that they get the right thing in the right place. Get them to come up with question, but guide them on what they need to do with the stuff cause just for management purposes really.</td>
<td>For running smoothly and getting it quickly probably the second one. For the children’s learning with an older class I think the first one would work. For the younger class they would need more instruction. 4th 5th, up they should be able to do it but it would depend on your class and how independent learners they are. At the moment a lot of my children here wouldn’t be very independent.</td>
<td>I think the first one doesn’t give enough. If that was me sitting there the first one doesn’t give enough information I don’t know what I’m supposed to be doing it’s nice to have something to follow, and actually in all fairness she hasn’t given the answer or even hinted at the answer.</td>
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</table>
Dichotomy 2a: Induction/Deduction

The premise of this induction/deduction dichotomy is: learning should move from specific information to a generalization. Students examine facts, data, experimental materials or visual information and form a generalized idea, the related science concept, about them. VS. Learning should move from the general concept to specific information. The teacher first explains the general science concept and then supports it by giving the students facts and asking them to apply the concept to other specific examples.

<table>
<thead>
<tr>
<th>Induction (1)</th>
<th>More Induction than Deduction (2)</th>
<th>A mix between the two (3)</th>
<th>More Deduction than Induction (4)</th>
<th>Deduction (5)</th>
</tr>
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<tr>
<td>they have to discover on their own. It’s important not to tell them everything at the beginning, otherwise they’ll say oh I know it all, so later in the week I’m going to do the experiment on paper airplanes with forces and I am just going to have the templates ready and let them just discover things for themselves and then give them the paper clips and ask them if there is weight on it which way does it turn you know things like that. At the very end we’ll decide what was our result what was our conclusion, but I think at the very beginning just give them the basics that they need and let them discover</td>
<td>It’s normal for teachers to be in full control, not letting them explore first things but I think they learn more by exploring themselves, figuring things out by themselves and getting their own ideas. But in the infant level you have to have a lot more control over them you know because they’re they’re only starting school, they’re starting from the beginning and you have to have more control. More freedom later on, because they’re able to work on their own more</td>
<td>I think you need a bit of both, because certain things if you want them to know the definition, if they’re not getting it and they need to know it, then you need to be explicitly teaching them. Whereas if it’s a kind of an experiment and the whole idea is that they will take something from it then obviously you’re not going to tell them, you want them to figure out themselves whereas if it’s a more theoretical kind of thing then you’ll need some directed teaching on it.</td>
<td>I think the second one would work a lot better with younger classes, because you can’t really give them out stuff and let them off because they would go haywire but at the same time I think it’s important, maybe even later in the year to allow them to do that.</td>
<td>The first one it would be great if it just they were able, their, I think their thinking is very like hmm is very restricted to what we say and they learn from us. But they find very difficult in anything you do, no matter what subject, to start up the thinking process, you, you have to be constantly on them, throwing them ideas and how to again they develop from there.</td>
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Dichotomy 2b: Inductive/deductive activity

The premise of this Inductive/deductive activity dichotomy is: The teacher states that students will learn about the concept of magnetism by building and playing with magnetic cars. The teacher asks them to play with the cars and make them move by applying the magnets. Through this Inductive, the students induce an understanding of the scientific concept VS. The teacher states that the students will learn about the concept of magnetism, beginning with the teachers’ explanation of the concept. After, the teacher asks the students to build the cars and make them move by applying the concept of magnetism that was explained to them.

Note: the deductive video was showed first.

<table>
<thead>
<tr>
<th>Inductive (1)</th>
<th>More Inductive than deductive activity (2)</th>
<th>A mix between the two (3)</th>
<th>More deductive than Inductive activity (4)</th>
<th>Deductive activity (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yah, the second one, because they get to experiment it, they figure it out, they get magnets pretty quickly, and what happens, and then discuss at the end. I would say generally the second, it’s just a question of man power, giving out resources and monitoring it but definitely the second one is a better way of teaching, let them figure out and let them come back with their comments, they learn more that way</td>
<td>I thought the first one there was just too much; the teacher was doing too much talking. I was getting confused (laugh) it’s just too much, when she just starts going on about north and south you know it is hard to know how much is their prior knowledge of magnets but I like the second one, they were allowed to make the car so that that was included in the design and making as well. I just taught the first one was a bit to structured maybe. Just too much talking and I find the children would zone out, you need to break it down in steps</td>
<td>There is a bit of both because in the first she actually show them the magnets so they actually know what a magnet is. Some kids wouldn’t know what a magnet actually is so they need to actually know in order for them to understand whereas there in the second one they’re just seeing the car, they don’t actually understand what the magnet is the magnet is the key of the lesson not the car</td>
<td>think before, yah, I think I’ll explain before and, with the older classes once again it would probably be nicer for them to go and find out by themselves how it works, but definitely the younger classes I think I’ll explain before giving out the magnets, how they work</td>
<td>they were given a lot more information in the first one, was very vague the second way, I don’t think that they would know with the second one really, I think the first one explained a lot better, she talked through it first and she gave them an idea how the magnets work and what directions the poles should face and everything, then she explained how to make the cars and then she told them to have a go at it, with the instructions, and then she said we’ll observe our results</td>
</tr>
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</table>
Dichotomy 3a: Creativity vs guidance

The premise of the creativity/guidance dichotomy is: science should be taught in a way to promote creativity. To do so, teachers should reward and encourage new ideas and perspectives to promote divergent thinking VS. In science, creativity is secondary and a distraction from the purpose of the lesson. Success in science is achieved by having the students follow a structured approach to the solving of problems.

<table>
<thead>
<tr>
<th>Creativity (1)</th>
<th>More creativity than guidance (2)</th>
<th>A mix between the two (3)</th>
<th>More guidance than creativity (4)</th>
<th>Guidance (5)</th>
</tr>
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<tbody>
<tr>
<td>I think creativity is so important, because it’s so linked in, I know last year we did the water cycle, through arts, you know, and then they had to make through the story and follow the drop of water, that moved around and then they made their own collage, of the water cycle. And it was so linked so they can see it visually. So, I think, definitely, primary school, creativity is important.</td>
<td>I know what they say, to teach the steps solve to the problem so they can do it themselves or else let them do it creatively, figure out themselves, there’s different types of learners, people actually figure out things in a different way some would have more of an analytical mind others’ more creative way of looking at things so kind of it doesn’t help every learner if you teach them one method. It’s more let them explore themselves, the freedom, letting them give all their ideas to listen to all their ideas cause you can’t, you’re cutting off the creativity side of things</td>
<td>I’d agree with both of those, I think it’s important for the students to be allowed to be creative but at the same time they have to have the knowledge base behind that, it’s important that in terms of creativity there are times where they would o need structure in terms of how they’re going to approach it, especially in science I think it’s very relevant. I mean, they have to have controls in different experiments but you also have to be able to say these are the steps you’re going to take, so they have a plan of it</td>
<td>I do think it’s good for them to form problem solving techniques and you know have a good idea of how to solve problems and come to conclusions and stuff like that, but I think there is definitely room for a certain amount of creativity, as well, you know, not totally restrict them.</td>
<td>At this age you tend to give them skills that would help them problem solve, so, structured. I think they need structure at this age, they are so young they need structure and guidance and clear defined rules.</td>
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Dichotomy 3b: Student/teacher led construction of object

The premise of the Student/teacher led construction dichotomy is: Students design a toy using the principle of a lever. The teacher explains the lever principle and students apply that principle in the design of a toy of their choice. VS. Students design a toy using the principle of a lever. The teacher explains the lever principle and students apply that principle in the design of WAG, a dog which sticks out its tongue when you wag its tail.

<table>
<thead>
<tr>
<th>Student led construction (1)</th>
<th>More student led than teacher led (2)</th>
<th>A mix between the two (3)</th>
<th>More teacher led than student led (4)</th>
<th>Teacher led (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I think the second one because, they’re kind of guided to much in the first one OK, because they’re even told what toy to make at the end whereas they kind of use their imagination in the second one, they can become more creative learn more that way.</td>
<td>they both started similar enough and she had to explain the concept first I suppose the second was a bit more open ended that they weren’t prescribed a particular thing to do so I think it would have left more scope for the students to experiment with their design and maybe after leave the discovery that if you wag the tail the tongue will stick out, the dog after. again it would depend on the children I think. The second way would be good, for them to figure out, it would promote their creativity and ways to solve how to do it. Again, it depends on the groups and the class sometimes that might just not work with everybody so they might need to try and make the dog, there’s still some value in that as well.</td>
<td>I like the way she kind of makes them make the same toy, so they all get. I suppose what we would probably do we would probably make one toy together and then hmm allow the children then to make their own toy. I think it would be important so that they can get the concept and then we could maybe make the earlier finishers or the children that were able to make a different toy.</td>
<td>I think they could find it hard try to think of a toy of their choice and that the focus could go away from what a lever is to what toy am I going to make, so I think the first one where they’re given an example. You’re going to make the dog with a tongue that you know wags or a tail whichever it’s better. Just because I think you would lose the purpose of the lesson.</td>
<td></td>
</tr>
</tbody>
</table>
Bibliography


Regan, E. (2009). I liked the experiment because there aren't too many people who come into school to burn money: promoting participation in the sciences with chemical magic. *Improving Schools 13*(3) 261-276.


