International Journal of Science Education

ISSN: 0950-0693 (Print) 1464-5289 (Online) Journal homepage: http://www.tandfonline.com/loi/tsed20

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To cite this article: Diogo Martins Gomes & Veronica McCauley (2016) Dialectical dividends: fostering hybridity of new pedagogical practices and partnerships in science education and outreach, International Journal of Science Education, 38:14, 2259-2283, DOI: 10.1080/09500693.2016.1234729

To link to this article: http://dx.doi.org/10.1080/09500693.2016.1234729

Published online: 02 Oct 2016.

INTERNATIONAL JOURNAL OF SCIENCE EDUCATION, 2016
VOL. 38, NO. 14, 2259–2283
http://dx.doi.org/10.1080/09500693.2016.1234729

Dialectical dividends: fostering hybridity of new pedagogical practices and partnerships in science education and outreach

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ABSTRACT
Science literacy has become socially and economically very important. European countries stress that science graduates are fundamental for economic growth. Nevertheless, there is a declining student participation in science. In response, there has been a call to change the way science is taught in schools, which focuses on inquiry methods rooted in constructivism. Universities and other organisations have responded by developing outreach programmes to improve student engagement in science. Given this context, there is a necessity for research to ascertain if this new relationship between outreach and education is worthwhile. 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 a teacher-outreach partnership. For this, qualitative and quantitative methods were employed, taking a dialectic pragmatic stance. Contradicting the recurrent view, teachers and outreach providers revealed favourable views in relation to constructivism, despite recognising barriers to its implementation. These results support a partnership between teachers and outreach practitioners and the realisation of the hybrid role of each participant. The results also reveal an important dynamic in outreach access to schools. Specifically, the outreach connected teachers acted as gatekeepers by negotiating access into their colleagues classrooms.

ARTICLE HISTORY
Received 9 December 2015
Accepted 6 September 2016

KEYWORDS
Elementary school; science outreach; constructivism

Introduction

Governments worldwide, realising that science influences every aspect of modern life, aspire to boost scientific capacity in order to promote economic growth and develop a well-informed and empowered society (DJEI [Department of Jobs, Enterprise and Innovation], 2015; European Commission, 2016; Itzek-Greulich et al., 2015; Osborne & Dillon, 2008). Traditionally, an increase in scientific capacity has been targeted through the schools and these efforts have been carried out through curricular change and teacher training (Bell, Lewenstein, Shouse, & Feder, 2009). Apart from the formal experiences, students have abundant opportunities to be involved with science, for example after-school science programmes, open day visits to universities or science camps (Bell et al., 2009). Efforts to provide informal opportunities to engage with science and integrate

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Supplemental data for this article can be accessed at doi:10.1080/09500693.2016.1234729.

it with formal learning are comparatively new (Tressel, 1994; Woods-Townsend et al., 2016). Therefore, the links to formal learning are not usually planned or accounted for (Crane, 1994; Monteiro, Martins, Souza, & Carvalho, 2016).

Nevertheless, in recent years, informal opportunities have increased in number (Holmegaard, Madsen, & Ulriksen, 2014; Stocklmayer, Rennie & Gilbert, 2010; Tan, Barton, Kang, & O'Neill, 2013) in response to the shortage of science graduates (European Commission, 2011; Osborne & Dillon, 2010; Regan & DeWitt, 2015). Informal learning activities are being recognised as a supplement to the formal learning of science (European Commission, 2007; NSF [National Science Foundation], 1998; Stocklmayer et al., 2010).

In Ireland, informal opportunities are also increasing, reflecting this global trend (Davison, McCauley, Domegan, & McClune, 2008; SFI [Science Foundation Ireland], 2014a). 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, Murphy, & Veale, 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 science outreach programmes, this research examines them in the context of primary-level education in Ireland. This study situates between science outreach and science education in order to promote a more efficient collaboration between both areas and a more engaging science experience. The next sections analyse (1) the curricular change in science education, particularly at primary level (2) how these reforms are accepted by teachers and (3) the role of science outreach in science education.

Curricular change in science education

Changing science education to make it more engaging and meaningful for students is not a new objective. 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 (McCoy, Smyth, & Banks, 2012; Osborne & Dillon, 2010). In parallel, several authors have reported a decline in number of students pursuing a science-related career (Fortus & Vedder-Weiss, 2014) and the declining participation in the physical sciences (Hampden-Thompson & Bennett, 2013).

The European Commission (2007) states that in order to increase interest in science, science education needs to change and suggests that this involve 'a reversal of school science-teaching pedagogy from mainly deductive to inquiry-based methods' (p. 2). Such claims are supported by evidence presented by several authors such as Koksal and Berberoglu (2014) who document the positive effect of a guided-inquiry approach on sixth-grade Turkish students' cognitive as well as affective characteristics; and Jocz, Zhai, and Tan (2014) who suggest that inquiry learning can increase Singaporean students' interest in school science when the everyday applications of science are emphasised and peer discussion is encouraged.

Inquiry learning is stressed in the Irish primary-level curriculum (DES [Department of Education and Skills], 1999). The curriculum advocates that students need to plan, design and perform investigations in order to learn and make sense of science. Furthermore, the curriculum explicitly values a constructivist approach. This constructivist approach recommends starting from the child's ideas and favouring a developmental view (DES, 1999). Finally, creativity in science and the learning of science are highlighted.

From curricular guidelines to practice in schools

Curricular reforms acknowledge 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; Tytler, Osborne, Williams, Tytler, & Cripps Clark, 2008).

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 (ASTEC [Australian Science, Technology and Engineering Council], 1997; HM Inspectors of Schools, 1999; Varley et al., 2008). These reports indicate that primary-level teachers are reluctant to teach science. Research indicates that many do not have the preparation, confidence or the belief that science should be one of the most relevant subjects in primary education (Avraamidou, 2013; Kim & Tan, 2011). Mulholland and Wallace (2003), for instance, assert that pre-service early childhood teachers see themselves as a 'non-scientists'. Nichols and Koballa (2006) conclude that primary-level teachers lack of science knowledge. Thomson and Gregory (2013) conclude that shifting primary-level teachers' practices towards supporting a constructivist approach will first require changing their beliefs about science teaching and learning. Furthermore, Mintzes, Marcum, Messerschmidt-Yates, and Mark (2013) report the relevance that self-efficacy plays in implementing constructivist practices. They 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 that by Kanter and Konstantopoulos (2010) that states 'if teachers are lacking in content knowledge or pedagogical content knowledge, they may not be able to employ the inquiry-based aspects' (p. 174).

In Ireland, only 10% of Irish primary-level teachers have science in their university degree (Eivers & Clerkin, 2013). The TALIS (OECD [Organisation for Economic Co-operation and Development], 2010) international survey programme concludes that teachers in Ireland use the traditional model of teaching even more than teachers in other countries. 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.

Science outreach: a remedy for a broken system?

Stocklmayer et al. (2010) argue that change in science education does not seem achievable in the near future. Schools systems have shown repeatedly to be resisting it. In response to these concerns, science outreach lies 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 European Commission (2007) advocates that science outreach can accelerate the pace of change in science education.

In Ireland, SFI, a state agency, is the primary investor in scientific research (SFI, 2014a). As such, the SFI has strongly invested in science outreach (SFI, 2014a). 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 with strategies such as SFI Smart Futures 2014–2017 (SFI, 2014b). Its objective is to increase the uptake of science in second and third level by 10%. According to this strategy, SFI are charged with organising visits by volunteer research staff to schools to showcase their research, discuss more general science issues and promote careers in science (SFI, 2014b).

SFI has a specific programme for science outreach at the primary level, Discover Primary Science and Maths (DPSM). DPSM (2014) provides resources for teachers and students to develop inquiry learning activities and training for primary-level teachers (DPSM, 2014). The DPSM outreach programme aims specifically to help teachers develop the Irish primary science curriculum.

Stakeholders envision a relevant role for science outreach in engaging students with science. Research conducted by Henriksen, Jensen, and Sjaastad (2015) suggest that stakeholders wishing to improve science participation need to consider partnerships with educational institutions. Fallik, Rosenfeld, and Eylon (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 recognise 'the need to create productive collaborations between informal science education organisations and schools' (p. 70). 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 at primary level and outreach.

Research aims

This study is situated between two spaces. The first space is science education at the primary level, the second, science outreach initiatives. This study is focused on university-driven science outreach because the latter forms the majority of outreach initiatives in Ireland (Davison et al., 2008). It analyses and compares the views that teachers and outreach practitioners have regarding the objectives envisaged by curricular reforms, in order to understand the potential for fruitful partnerships. The overall aim of the research is to examine and compare primary teachers' and science outreach practitioners' understanding and perception of a constructivist approach to science teaching, in order to improve the hybrid practice of science education/outreach in Ireland.

The methodological phase of this research is guided by two research questions:

RQ 1: What are primary teachers' and science outreach practitioners' understanding and perceptions of a constructivist approach to science teaching?

RQ 2: How do primary teachers and science outreach practitioners understand conceptual and pedagogical dilemmas in science teaching and learning?

Methods

To address the research questions, this study follows a dialectic pragmatic stance. Dialectical pragmatism emphasises that 'pragmatism for mixed methods takes quantitative and qualitative methods seriously but then develops a synthesis of the research study' (Teddlie & Tashakkori, 2009, p. 73). Since this study uses qualitative and quantitative methods, it employs deductive and inductive logics to address the confirmatory and exploratory research questions (Johnson & Onwuegbuzie, 2004). For the purposes of this paper, the authors will draw reference from a semi-structured interview process that allowed for both qualitative and quantitative analysis.

Sampling

The semi-structured interview designed for this study obtained both quantitative and qualitative information, with an emphasis on the latter.

This stage of the study followed a purposive sampling strategy (Cohen, Manion, & Morrison, 2007) for each research participant group, teacher and outreach practitioner. It 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 who worked with primary-level students. Thirty outreach practitioners were interviewed. For the teacher population, the objective was to select teachers from large and small schools. Small schools are schools with less than 180 pupils (Ó Slatara & Morgan, 2004). Four primary schools were selected, two small schools and two large schools. Thirty-one teachers were interviewed. To follow ethical guidelines (Cohen et al., 2007), access was negotiated through the principals. Table 1 presents the selected characteristics of the participants. The number of participants selected for interview is justified following principles from the constant comparative process (Onwuegbuzie & Collins, 2007).

Dilemmatic nature of the interview

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. As such participants were presented with six dilemmas. 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), as illustrated in Figure 1. The conceptual dilemmas are drawn from relevant popular theorists who present the concepts in a concise manner and the pedagogical application is sought from activities recommended for the Irish primary science curriculum.

These dilemmas are based on concepts and practices, constructivist and inquiry based methods that are popular in science education curricular reform (European Commission, 2007) and specifically championed in the Irish primary-level curriculum (see Figure 2).

The reasoning behind the choice of a dilemmatic methodology is now explained. For this research, contextualised and specific dilemmatic cases were presented to the

Table 1. Selected characteristics of the participants.

Teachers		
Years of experience	Years	Frequency
	Less than 3	9
	3–10	14
	More than 10	8
	Total	31
Outreach initiatives in the classroom		Frequency
	Yes	21
	No	10
	Total	31
Size of the schools teachers taught in		Frequency
	Small	8
	Large	23
	Total	31
Years the teachers were teaching		Frequency
	Infant classes (4–6 years)	10
	1st and 2nd classes (6–8 years)	15
	3rd and 4th classes (8–10 years)	4
	5th and 6th classes (10–12 years)	2
	Total	
Biological sex		Frequency
	Female	29
	Male	2
	Total	31
Outreach practitioners		
Role		Frequency
	Ph.D. Student	13
	Post Doc/staff	17
	Total	30
Years of experience	Years	Frequency
	Less than 3	13
	3–10	13
	More than 10	4
	Total	30
Area of Science		Frequency
	Science	6
	Computer science	3
	Physics	3
	Biology	16
	Engineering	2
	Total	30
Biological sex		Frequency
	Female	18
	Male	12
	Total	30

participants. The cases followed the classic definition of dilemma in which two conclusive arguments (dichotomy) are presented in opposition (Tillema & Kremer-Hayon, 2002). The dilemma framework can lead the research participants to interrogate their own beliefs and question institutional routines (Windschitl, 2002). The dilemmatic reflection is used to better facilitate the dialectical thinking of the participants. This reflection allows the participants to engage in inductive and deductive thinking (dialectically) when confronted with the dichotomies (Bencze & Bowen, 2009). To promote deductive thinking, they are explicitly presented with opposing perspectives. Afterwards, the participants engage in inductive thinking, as they develop claims about the dilemma, when asked to relate to their own practice. The dialectic reflection allowed the unravelling of the tensions and contradictions faced by practitioners when having to make choices during their practice (Yoon & Kim, 2010) and the understanding of the perceptions of the participants

Conceptual dichotomies	Pedagogical dichotomies
Autonomy ←→ Dependency (McRobbie &Tobin, 1997; Davis, 2003)	Open inquiry ←→ Guided Inquiry Activity selected to be presented according to the dialectical poles: - Colored Plant (DPSM, 2014) (from the curricular strand: investigate factors that affect plant growth)
Induction ←→ Deduction (Reid, 2011; Kirschner, Sweller & Clark, 2006)	Inductive activity ←→ Deductive activity Activity selected to be presented according to the dialectical poles: - Build a magnetic car (DPSM, 2014) (from the curricular strand: learn that magnets can push or pull different materials)
Creativity ←→ Guidance (Beghetto, 2007; McRobbie & Tobin, 1997)	Student led-construction of object ←→ Teacher-led construction of object Activity selected to be presented according to the dialectical poles: - Wag: the dog (DPSM, 2014) (from the curricular strand: explore how levers may be used to help lift different objects: design and make a toy using a lever')

Figure 1. Dichotomies that guide the semi-structured interview.

in relation to a constructivist approach to science teaching. The overall aim was to provide an insight into a strategy to improve science education/outreach practice in Ireland.

In order to present the participants with the conceptual dichotomous choices, theoretical explanations/quotes were presented in the form of a short video clip. The opposing perspectives were based on claims about constructivist approaches drawn from the science education literature. This methodology is congruent with previous studies in which teachers analysed claims from researchers about inquiry learning (Bencze & Bowen, 2009). Although conceptual dilemmas are core to understanding epistemological positions, pedagogical dilemmas are of no less relevance. Pedagogical dilemmas deal with the concrete (Windschitl, 2002). They are contextualised activities that teachers and outreach practitioners develop with their students. The pedagogical choices teachers make in their

Constructive approach, epistemological autonomy of the children	Less deductive, more inquiry driven inductive learning	The importance of creativity
The constructivist view of learning involves: • beginning from children's ideas and practical experiences • reflecting on where children are in the progression towards the development of more scientific ideas • providing opportunities for children's ideas to be tested • assessing the extent of any change in ideas and in the skills of working scientifically (Teacher Guidelines, p. 2)	Children learning by investigating is at the heart of the Science Curriculum. Children are encouraged to work as scientists as they investigate and explore their physical and natural surroundings. These first-hand experiences help them to find answers to problems themselves by exploring their own environment. The curriculum supports children in developing skills of enquiry during this investigative work: observing, asking questions, suggesting explanations, predicting outcomes, planning investigations or experiments to test ideas and drawing conclusions. (Curriculum Online, 2011) Children in primary schools construct scientific ideas and concepts based on available evidence. These ideas and concepts will be refined as the children work in more demanding contexts and develop more open-ended investigative approaches to solving problems. (Teacher Guidelines, p. 3)	Science is a human endeavour that depends on the creativity and imagination of people as they reflect critically to make sense of their experience. It is important that learning activities promote curiosity and enjoyment, so that pupils develop a lasting interest in science. (Teacher Guidelines, p. 3)

Figure 2. Statements from the Irish primary-level curriculum (DES, 1999).

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 & Berlin, 2012). By presenting both, it is possible to compare participants' views of their conceptual and pedagogical choices. The pedagogical dilemmas were developed in two steps, as evident in Figure 3. 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 contextualise them in practice, the dilemmas take into account the Irish curriculum and activities prescribed in it. The three activities were selected from the DPSM website and presented in two ways. Flower power activity was presented as an open inquiry and a structured one following the definition of Blanchard et al. (2010). Building a magnetic car was presented as an inductive activity (Taba & Spalding, 1962) and as a deductive one according to the advance organiser model. Finally, Wag the dog was presented as a student-led construction, which increases uniqueness and therefore creativity (Beghetto, 2007), or a teacher-led construction.

Quantitative analyses of the interview

Although the interview was qualitative in nature, as the practitioners were asked to rate their teaching and learning preference in relation to the six dilemmas, it was possible to develop a quantitative measurement and translate their rating of each dilemma into data. 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,

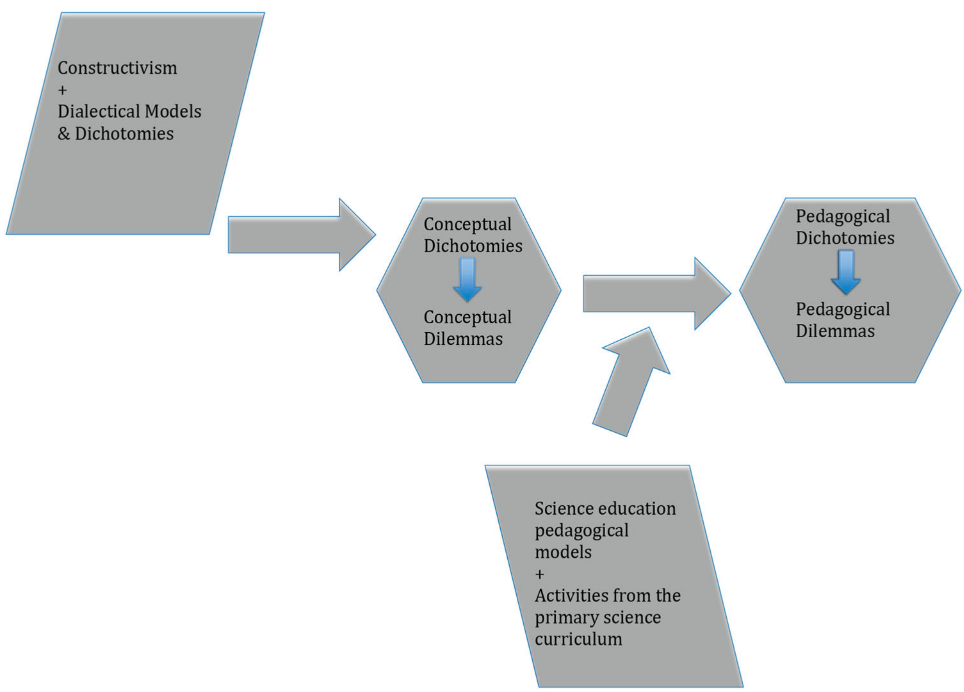

Figure 3. Framework for the development of the pedagogical dilemmatic cases.

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. This was done for each of the six dilemmas. Teachers and outreach practitioners' responses were used to define the scales. Figure 4 illustrates one of the six scales defined. The other five can be found in the supplementary file.

The responses were coded separately by three researchers. After the initial coding process, the three researchers consulted with each other to ensure agreement. A communicative validation by comparing the four transcripts between the three researchers was carried out. After this consultation, both intra- and intercoder agreement was above 90%. This is above the range defined by Miles and Huberman (1994). SPSS 20 software was used for the statistical analysis. Once participant information was entered, the data were checked and cleaned for errors. The following data analysis was carried out: descriptive statistics on the variables of interest, which included the mean, standard deviation, the range of scores, kurtois and skewness and a Mann–Whitney *U*-test was used to test for differences between teachers and outreach practitioners for the different dichotomies.

Qualitative analyses of the semi-structured interview

The qualitative data from the interviews were analysed to interpret how participants understand conceptual and pedagogical dilemmas in science teaching and learning. 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 the qualitative analysis of the interview transcripts borrowed principles from the constant

Autonomy (1)	More autonomy than dependency (2)	A mix between the two (3)	More dependency than autonomy (4)	Dependency (5)
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	I agree more with the first one that you start form 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	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	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	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

Figure 4. Five-point scale for the dichotomy Autonomy/Dependency.

comparative coding process (Green, 2008). In this process, three concepts were used: codes, categories and themes (Chenail, 2008). The codes, categories and themes explored in this study are presented in Figure 5.

The coding started with abstracting obvious topics from the transcripts. This 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. Second, the initial coding continued with NVivo 10.2 which enabled the grouping of related concepts. In NVivo these related concepts are organised 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). 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 19 initial codes, as seen in Figure 5. Different methods available in NVivo were used to reflect on the codes that were developing. First, code files permitted to analyse the consistency and frequency of the code. Second, framework matrices were created to analyse the codes throughout the different research participants.

Analytical stage	Outcome
Codes	19 codes including: Connecting theory to practice, context of the student, discover their learning, age dependent, level of the students, their experience as students, student interest, active, explore, experiment, there is no time, cover the curriculum, get the concept, structure, the methods, concrete learning, need an expert, deductive and inductive, experience of outreach.
Categories	Development of 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, experience of outreach, need an expert.
Themes	Condensed to 3 themes: Tools to foster students learning, Tensions between the ideal and the real, Dynamics of Outreach.

Figure 5. Analytical stages of the qualitative analysis.

The analyses of the framework matrices were used to disconfirm 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 a few (5) outreach practitioners referred to this code, it was not developed into a theme. The framework matrices allowed the development of the initial nodes. Further analysis was carried out to attain the 14 higher order categories that are depicted in Figure 6.

Categories	Anchor example	Teachers (frequency)	Outreach Practitioners (frequency)
Context of the student	I think it depends on the background of what they [the students] have been learning (Interview 60)	13 in 31	21 in 30
Discover their learning	they figure things out, they discover things out themselves (Interview 8)	22 in 31	24 in 30
Age dependent	I think it has to be age dependent (Interview 3)	25 in 31	15 in 30
Level of the student	depends on class level as well you know, you do really have to gage your class and see what they're able to work (Interview 9)	13 in 31	12 in 30
Students interest	if they are doing something that they like then they will be more engaged (Interview 19)	20 in 31	19 in 30
Explore	You need to give the time to explore because science isn't s omething you can learn by rote (Interview 27)	18 in 31	12 in 30
Experiment	Science is a lot about the investigative cognitive procedure and hmm them learning to experiment (Interview 14)	6 in 31	13 in 30
There is no time	You have so many children to deal with and you have to get it done in a certain amount of time (Interview 40)	11 in 31	10 in 30
Cover the curriculum	it's always better to do something practical but it's just a big big curriculum. (Interview 3)	12 in 31	13 in 30
Get the concept	That was the most efficient way of ever understanding concepts (Interview 41)	14 in 31	20 in 30
Structure	Definitely we have to give them [the students] more guidance, more structure (Interview 13)	21 in 31	17 in 30
The method	I think learning rigor and learning scientific rigor in science and experimental methods and that you make an hypothesis and that you have to test it, I think that is very valuable (Interview 27)	13 in 31	18 in 30
Experience of outreach	that's what we try and do with our outreach it's to create something that is more open ended and giving students time (Interview 31) 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 (Interview 20)	13 in 30	15 in 30
Need an expert	Science is a whole area I think you you'd nearly need a science teacher to come in and do that, a specialist (Interview 15)	16 in 31	1 in 30

Figure 6. Categories of the qualitative analysis with anchor examples and frequency for each.

Themes	Respective categories
Strategies to foster student learning **(61 in 61 research participants)**	Context of the student, discover their learning, students interest, explore, experiment, get the concept, structure, the method
Tensions between the ideal and real **(61 in 61 research participants)**	age dependent, level of the students, there is no time, cover the curriculum, need an expert
Dynamics of outreach **(25 in 61 research participants)**	Experience of outreach

Figure 7. Themes of the qualitative analysis and corresponding categories.

The next stage corresponded to the categories being merged and re-named into three main themes: Strategies to foster students learning, tensions between the ideal strategies and the real classroom, the dynamics of outreach, as seen in Figure 7. Through axial coding, the most relevant codes were selected with the data being sorted into the different themes (Ritchie & Jane, 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 14 themes 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 three main themes.

Quantitative results

The semi-structured interview sought to examine and compare how the participants understand conceptual and pedagogical dilemmas in science teaching and learning. When reflecting on the dichotomies presented in the dilemmatic cases, participants argued mostly for concepts and practices that gave more control to the student in the learning process or a mix between the two, as seen from Figure 8.

The dichotomies in which teachers were more divided between the poles were Creativity/Guidance, Open/Guided Inquiry and student/teacher-led construction of object, although these differences were not statistically signficant. 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, in contrast, the relevance of a structured approach to problem-solving.

The results of the analyses of both teachers' and outreach practitioners' responses to the dichotomies revealed some differences between the two groups. The dichotomies in which teachers were more divided in their views were pedagogically based (Open/Guided Inquiry

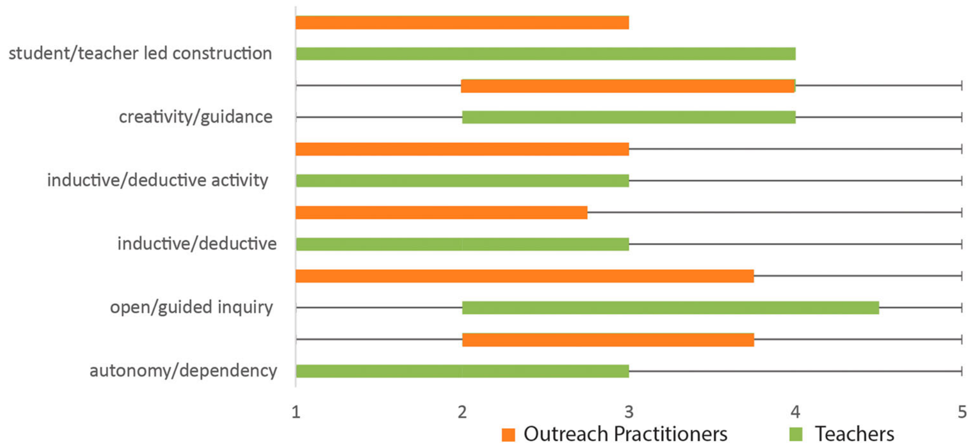

Figure 8. Boxplots of the participants' responses to the six dilemmas.

and student/teacher-led construction of object). For outreach practitioners the two dichotomies which revealed a divide in their views were conceptual (Autonomy/Dependency and Creativity/Guidance). These results indicate that teachers, when discussing conceptual dilemmas, seem to be more in favour, *from a theoretical standpoint*, for example, of students controlling their own learning, than outreach practitioners. On the other hand, outreach practitioners seem to be more in favour, *from a classroom practice standpoint*, of students controlling their own learning (pedagogical dilemmas). The

Table 2. Mann–Whitney *U*-test comparing the scores of teachers and outreach practitioners for each dichotomy with medians as well as 25th and 75th percentiles.

	Autonomy/ Dependency	Induction/ Deduction	Creativity/ Guidance	Open/ Guided Inquiry	Inductive/ Deductive Activity	Student/ teacher-led construction
Mann–Whitney U	315.0	367.5	404.0	335.5	413.5	340.0
Z	−2.1	−1.3	−.48	−1.7	−.37	−1.5
Asymp. Sig. (2-tailed)	.04	.20	.63	.08	.71	.13
A. Grouping variable: teacher/outreach						

	Variable	Teachers	Outreach practitioner
Autonomy/Dependency	25th	1	2
	Median	2	3
	75th	3	3.75
Induction/Deduction	25th	1	1
	Median	2	2
	75th	3	2.75
Creativity/Guidance	25th	2	2
	Median	3	3
	75th	4	4
Open/Guided Inquiry	25th	2	1
	Median	3	2
	75th	4.5	3.75
Inductive/Deductive Activity	25th	1	1
	Median	1	1
	75th	3	3
Student/teacher-led construction	25th	1	1
	Median	3	2
	75th	4	3

Mann–Whitney test supports this result as it shows that there is only a significant difference between teachers (Md = 2, $n = 31$) and outreach practitioners (Md = 3, $n = 30$), $U = 300.0$, $Z = -2.099$ $p = .040$ for the dichotomy Autonomy/Dependency. The effect size is small $r = .27$ as defined by Cohen (1988), as seen from Table 2. The effect size was calculated by using the formula $r = z$ / square root of N where N = total number of cases given in Pallant (2010).

Qualitative results

The qualitative analysis of the interviews allowed depth of reflection beyond quantification. It revealed the reasoning behind participants' choices in relation to how they 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. The core ideas which the three themes revealed are now summarised.

Strategies to foster student learning

The first theme, Strategies to Foster Student Learning; examined the various ways the participants articulated perspectives that best promote student learning. Many of the participants (49 in 61 participants) recognised that interest was an important factor to motivate students to learn. For example, Jennifer, who has three years of experience in 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 recognising '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). Furthermore, the participants associated the role of interest with the need to contextualise learning in students' realities (44 in 61 participants). Martha, for instance, argued: 'you should start from what they know and what they want to know' (Interview 6, Martha, teacher for 21 years). The participants also argued that in their practice, they value students' reflected exploration and the scaffolding of the teacher (40 in 61 participants). Other teachers and outreach practitioners also believe in the role of exploration in promoting student 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)

In addition to teaching science, Flora is emphasising the role of exploring as a strategy that is used across all subject areas as an initial teaching activity in her school. Julia, an outreach officer, also emphasises the role of problem-solving in relation to inquiry.

> 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. Inquiry and reflexion is built into the curriculum at primary level. So perhaps the two [inquiry/curriculum coverage] go hand in hand. (Interview 59, Julia, Outreach officer)

The visible difference here is that whilst several teachers mention the role of exploring, experienced outreach practitioners argue more specifically for inquiry and problem-solving (theme experiment: 13 in 30 outreach practitioners). For instance, Patricia, a Professor in medicine and developer of outreach programmes, argues the importance of problem-solving:

> They can still be taught problem solving but without it being completely directive and restrictive so I mean the scientific methods can be applied but it doesn't have to be rigid, creativity can come in and should. (Interview 30. Patricia, Professor)

This difference is again visible when Matilda, teacher, argues:

> Let them have control over things definitely, discover for themselves. It is better I think for them. [...] Just to give them the time to explore, that is what it is all about, science to me anyway. (Interview 58, Matilda, Teacher for 10 years)

The gradation from a discovery viewpoint of inquiry to a more sophisticated one (Biggers & Forbes, 2012; Davis, Petish, & Smithey, 2006) is evident here. Many of the teachers reflected on inquiry in science as an exploring activity, mostly student-directed. On the other hand, the most experienced outreach practitioners discussed problem-solving and inquiry learning in a more sophisticated way as the previous quotes exemplify.

Finally, some of the participants argued that exploration and learning of science are more fruitful if children are encouraged to work together, collaboratively. These respondents spoke to the value of strategic paired learning, with differing learning styles/abilities, in order to foster an improved learning experience. Lucy's response details this in relation to teaching in classes with a large volume of students.

> 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). The different strategies voiced by research participants indicated that many of these teachers and experienced outreach practitioners have an abundance of pedagogical knowledge, in particular, in relation to a constructivist approach to learning, as they drew reference to: eliciting learning from student experience, encouraging problem-solving and an inquiry approach to learning within both a guided and less guided structure, and finally the importance of collaborative learning. Nonetheless, it was also visible that experienced outreach practitioners have a more sophisticated view of inquiry than many of the teachers.

Tensions between the ideal and the real

The second theme revealed the reasoning behind why teachers often do not apply constructivist learning. Participants, when discussing science activities, rationalised their choice of giving less control to the students as: a lack of time (category there is no time, 21 in 61), the length of the curriculum (category cover the curriculum, 25 in 61) and the age and level students of the students (categories age dependent, 45 in 61 participants and level of the students, 25 in 61 participants):

> 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 twenty or thirty 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 reveals why, in their practice, teachers often do not apply constructivist practices. 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 recognises that open inquiry is the approach that would facilitate exploration: 'that they would figure it out'. She recognises that the approach that gives more control to the student is the best. Nevertheless, Anna sees the tensions and problems she would face in her classroom if she were to apply the open inquiry practice. She speaks to time constraints in light of effectively teaching large groups of children and offers a solution of additional help, to support a more ideal teaching situation. Therefore, she first chooses the guided inquiry and moves towards a more 'traditional' approach as the literature suggests (Levitt, 2002), yet only because she is being realistic about the demands of the classroom.

Anna was not the only teacher who mentioned the need of support (16 in 31 teachers mentioned it). Melanie discussed science at primary level in the following way:

> Science is a whole area I think you you'd nearly need a science teacher to come in and do that, a specialist. It would nearly need to have, for those specific areas, science, I think it would be good to have a teacher come in, if that was your area. (Interview 15. Melanie, Teacher for 11 years)

What Melanie is describing here is the lack of her science content knowledge. This lack of science content knowledge is not surprising as the majority of Irish primary-level teachers do have not have science in their degree (Eivers & Clerkin, 2013). Melanie is arguing that she would welcome an expert in science into her classroom. This lack of content knowledge impacts teachers' ability to implement inquiry learning and constructivist practices fully (Kanter & Konstantopoulos, 2010).

As a consequence of the perceived issues with primary-level teachers, outreach officers are tasked with bringing more open-ended/inquiry pedagogies to the classroom. But experienced outreach officers also perceive similar practical issues.

Jane, an outreach officer with more than 10 years of experience argues, regarding the same 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 child 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 when younger children could reach the question and that was very interesting. (Interview 50, Jane, Outreach Officer)

Jane, as many of the participants, recognises she has to adapt her teaching strategy to the age and level of the students. As she is not sure about how to adapt her science teaching strategy 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 recognises her role as an outreach officer but adapts according to the challenges she foresees in the classroom due to her pedagogical experience. Outreach practitioners are working on a boundary crossing zone. Boundary crossing usually refers to a person's transitions and interactions across different sites (Suchman, 1994), Furthermore, some of the practitioners, such as Jane, are revealing hybridisation as they are merging ingredients from different contexts to promote a new practice (Akkerman & Bakker, 2011). These practitioners are showing constructivist understandings and related issues mixed with their scientific expertise.

Despite many of participants revealing their pedagogical knowledge of different strategies, they argued why some strategies are not always possible. What the data suggest 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 primary science education from the outset may appear rather simplistic, but it is not. With that in mind, it still has a powerful contributory role to the classroom which this research reveals (at the least in terms of opening up the conversation of science pedagogy across stakeholders, at the most in terms of inviting content knowledge expertise).

Dynamics of outreach

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. This theme stems from the category experience of outreach (28 on 61 participants) where participants reflected on outreach from their viewpoint as teachers or outreach developers. The data permitted the conceptualisation of the gatekeeper dynamics that were involved in gaining access into primary schools by outreach participants. Teachers from the same school revealed different relationships with outreach, varying from those with a strong relation with outreach providers to those who had no relation.

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 organises many projects and her students participate in a great number of initiatives. Nevertheless, Karen, a teacher in the same small school, has a completely different experience:

> Karen: [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.
> Interviewer: But would you have people coming from the university to do science outreach?
> Karen: No, never. (Interview 21, Karen, teacher for 11 years)

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 extend to Karen's class. Karen indicates a reason why this might be so: 'science wouldn't be my 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 inviting outreach into 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.

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

> [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, […] we have a lot of science. (Interview 5, Beth, teacher for 7 years)

Again, there is a teacher who 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 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 who 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 depend on individual teachers. However, the fact that there is so little communication or shared practice within a school bespeaks systematic cultures of isolation, a challenge to be overcome if shared expertise is the future endeavour (Hargreaves & Fink, 2004).

The challenges of negotiating these layers of access were visible with other participant teachers. The participants' reasoning revealed an ad hocness in the provision of outreach. In some cases, there seems to be careful planning and collaboration between outreach practitioners and individual teachers who have a connection with outreach providers.

Nevertheless, in many cases it seemed to come down to the willingness of individual teachers to seek out science support themselves. The scenario in which the dynamics of access worked best was when the outreach connected teachers also act as gatekeepers. These teachers can be seen as hybrid practitioners as they are at the same time, teachers and promoters of outreach. The data suggested that the hybrid practitioners have a crucial role in promoting outreach in the school. Colleagues less familiar with outreach were more open to it after they had received a recommendation ('put in a good word') from a teacher they knew and respected. Although the formal access and authorisation was given by the principals, the true outreach gatekeepers were these particular teachers who advertised the outreach activity and as such negotiated access into their colleagues' classrooms. This has specific implications for outreach, as the data indicate that for the partnerships between teachers and outreach participants to work, it is not enough to obtain formal access to the school, it is also important to recognise that individual teachers have the keys to their own classroom.

Discussion

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 & Onwuegbuzie, 2004, p. 17). The dialectic stance implies taking 'quantitative and qualitative methods seriously but then developing a synthesis' (Teddlie & Tashakkori, 2009, p. 73). Different layers of analyses are presented.

First layer: outcomes of the quantification of interview data

The participants who were interviewed 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). These results challenge beliefs 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 (Avraamidou, 2013). Nevertheless, in this study, 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.

Second layer: qualitative outcomes of the interview, outreach gatekeepers and hybrid practitioners

The qualitative analysis of the interview revealed the pedagogical knowledge of teachers, which strengthened the view obtained from the binary choices the teachers made in the interviews. Many of the voices of the participant teachers and some experienced science outreach officers revealed that they are cognizant of multiple strategies advocated by constructivist education literature to foster student' learning. The pedagogical knowledge that teachers demonstrated revealed a strong argument against the view that a lack of constructivist practice was at fault in terms of concerns about primary science education. This does not align with literature findings as those described by Eivers and Clerkin (2013, p. 78) that characterised Irish classrooms (at second and sixth class level) as predominantly using whole-class teaching methodologies with pupils working by themselves. 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 participants 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 30 students). Participants engaged in a deductive-inductive dialectic immersion (Bencze & Bowen, 2009) and reflected upon their students and their context, and they could not 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). When many of the participants reflected on pedagogical approaches to teaching science, they recognised that the ones that give more control to the student are the best from a pedagogical standpoint. Nevertheless, the participants highlighted the tensions and problems they would face in the classroom if they were to apply open inquiry practices. Further, these teachers recognised their lack of content knowledge, which can impact their implementation of reform practices. 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.

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 a strong pedagogical knowledge and they also recognise the issues that teachers identified in relation to the complex reality of the classroom. Outreach officers have a valuable position as they can bring elements of one practice into the other (Wenger, 1998). At the same time, they face a difficult position because they are often seen as being at the periphery, with the risk of never fully belonging to or being acknowledged as a participant in any one practice. Therefore, the view of outreach as a solution to primary science education is problematic.

Finally, the voices of the different practitioners uncovered the dynamics of the relationship between teachers and outreach providers. The understanding of this dynamic is crucial in the development of partnerships. It was possible to identify an ad hocness in the provision of science outreach. The ad hocness is represented by the disparity between the frequencies of outreach amongst teachers of the same school. 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 impact students. In many cases, this ad hocness 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. Therefore, as the data indicate, for fruitful partnerships to happen, it is crucial to understand that individual teachers have the keys to their classroom, and to recognise the dynamics of outreach gatekeepers and layers of access.

Conclusion

The results of this study 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 resist reform and lack constructivist knowledge. The primary-level teachers who took part in this study revealed to be well informed and that teachers and outreach providers are in agreement about the barriers to constructivist approaches. Therefore, the attention should shift away from teacher blame, or strategies to support the science-blind teacher, towards supporting the teacher-outreach partnership. By doing this, it is possible to create more hybrid practitioners who could play a crucial role in blurring the boundaries between formal and informal sectors and so promote the enjoyment and engagement of students with science.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by Fundação para a Ciência e a Tecnologia.

References

Akkerman, S. F., & Bakker, A. (2011). Boundary crossing and boundary objects. *Review of Educational Research*, *81*(2), 132–169. doi:10.3102/0034654311404435

Australian Science, Technology and Engineering Council (ASTEC) (1997). *Foundations for Australia's future: Science and technology in primary schools*. Canberra: Australian Government Publishing Service.

Avraamidou, L. (2013). Prospective elementary teachers' science teaching orientations and experiences that impacted their development. *International Journal of Science Education*, *35*(10), 1698–1724. doi:10.1080/09500693.2012.708945

Beghetto, R. A. (2007). Does creativity have a place in classroom discussions? Prospective teachers' response preferences. *Thinking skills and creativity*, *2*(1), 1–9.

Bell, P., Lewenstein, B., Shouse, A. W., & Feder, M. A. (2009). *Learning science in informal environments: People, places, and pursuits*. Washington, DC: National Academies Press.

Benaquisto, L. (2008). Axial coding. In L. M. Given, (Eds.), *The Sage encyclopedia of qualitative research methods*. Los Angeles, CA: Sage.

Bencze, J. L., & Bowen, G. M. (2009). Student-teachers' dialectically developed motivation for promoting student-led science projects. *International Journal of Science and Mathematics Education*, *7*(1), 133–159. doi:10.1007/s10763-007-9115-6

Biggers, M., & Forbes, C. T. (2012). Balancing teacher and student roles in elementary classrooms: Preservice elementary teachers' learning about the inquiry continuum. *International Journal of Science Education*, *34*(14), 2205–2229.

Blanchard, M. R., Southerland, S. A., Osborne, J. W., Sampson, V. D., Annetta, L. A., & Granger, E. M. (2010). Is inquiry possible in light of accountability? A quantitative comparison of the relative effectiveness of guided inquiry and verification laboratory instruction. *Science Education*, *94*(4), 577–616.

Bryman, A. (2008). *Social research methods*. Oxford: Oxford University Press.

Butler, M. B. (2009). *Motivating young students to be successful in science: Keeping it real, relevant and rigorous*. Retrieved from http://www.ngspscience.com/profdev/Monographs/SCL22-0419A_SCI_AM_Butler_lores.pdf

Chenail, R. (2008). Categorization. In L. M. Given (Ed.), *The Sage encyclopedia of qualitative research methods* (pp. 72–73). Los Angeles, CA: Sage.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*. Hillsdale, NJ: Lawerence Erlbaum Associates.

Cohen, L., Manion, L., & Morrison, K. (2007). *Research methods in education*. London: Routledger Falmer.

Crane, V. (1994). *Informal science learning: What the research says about television, science museums, and community-based projects*. London: Research Communications.

Davis, E. A., Petish, D., & Smithey, J. (2006). Challenges new science teachers face. *Review of Educational Research*, *76*(4), 607–651. doi:10.3102/00346543076004607

Davison, K., McCauley, V., Domegan, C., & McClune, W. (2008). *A review of science outreach strategies north and south*. Armagh: Centre for Cross Border Studies.

Department of Education and Skills (DES) (1999). *Primary school curriculum: Science. Social, environmental and scientific education*. Dublin: Stationery Office.

Department of Jobs, Enterprise and Innovation (DJEI) (2015). *Enterprise 2025 Ireland's National Enterprise Policy 2015–2025 Summary Report*. Retrieved from https://www.djei.ie/en/Publications/Publication-files/Enterprise-2025-Summary-Report.pdf

Discover Primary Science and Maths (DPSM) (2014). *About discover primary science and maths*. Retrieved from http://www.primaryscience.ie/about.php

Eivers, E., & Clerkin, A. (2013). PIRLS and TIMSS 2011: Overview. In E. Eivers & A. Clerkin (Eds.), *National schools, international contexts: Beyond the PIRLS and TIMSS test results*. (pp. 1–13). Dublin: Educational Research Centre.

European Commission (2007). *Science education now: A renewed pedagogy for the future of Europe*. Brussels: Author.

European Commission (2011). *Progress towards the common European objectives in education and training*. Brussels: Author.

European Commission (2016). *Science education*. Retrieved from https://ec.europa.eu/programmes/horizon2020/en/h2020-section/science-education

Fallik, O., Rosenfeld, S., & Eylon, B. S. (2013). School and out-of-school science: A model for bridging the gap. *Studies in Science Education*, *49*(1), 69–91. doi:10.1080/03057267.2013.822166

Fleer, M. (2006). Early childhood teacher education. In K. Appleton (Ed.), *Elementary science teacher education: International perspectives on contemporary issues and practice* (pp. 107–124). Mahwah, NJ: Lawrence Erlbaum.

Fortus, D., & Vedder-Weiss, D. (2014). Measuring students' continuing motivation for science learning. *Journal of Research in Science Teaching*, *51*(4), 497–522. doi:10.1002/tea.21136

Green, O. D. (2008). Categories. In L. M. Given (Ed.), *The Sage encyclopedia of qualitative research methods* (pp. 71–72). Los Angeles, CA: Sage.

Hampden-Thompson, G., & Bennett, J. (2013). Science Teaching and Learning Science Science Teaching and Learning Activities and Students' Engagement in Science, (December), 37–41. doi:10.1080/09500693.2011.608093

Hargreaves, A., & Fink, D. (2004). The seven principles of sustainable leadership. *Educational Leadership*, *61*(7), 8–13.

Henriksen, E. K., Jensen, F., & Sjaastad, J. (2015). The role of out-of-school experiences and targeted recruitment efforts in Norwegian science and technology students' educational choice. *International Journal of Science Education, Part B*, 1–20.

HM Inspectors of Schools (1999). *Improving science education*. Edinburgh: HMSO.

Holmegaard, H. T., Madsen, L. M., & Ulriksen, L. (2014). To choose or not to choose science: Constructions of desirable identities among young people considering a STEM higher education programme. *International Journal of Science Education*, *36*(2), 186–215. doi:10.1080/09500693.2012.749362

Itzek-Greulich, H., Flunger, B., Vollmer, C., Nagengast, B., Rehm, M., & Trautwein, U. (2015). Effects of a science center outreach lab on school students' achievement – Are student lab visits needed when they teach what students can learn at school? *Learning and Instruction*, *38*, 43–52. doi:10.1016/j.learninstruc.2015.03.003

Jocz, J. A., Zhai, J., & Tan, A. L. (2014). Inquiry learning in the Singaporean context: Factors affecting student interest in school science. *International Journal of Science Education*, *36*(15), 2596–2618. doi:10.1080/09500693.2014.908327

Johnson, R. B., & Onwuegbuzie, A. J. (2004). Mixed methods research: A research paradigm whose time has come. *Educational Researcher*, *33*(7), 14–26. doi:10.3102/0013189X033007014

Kanter, D. E., & Konstantopoulos, S. (2010). The impact of a project-based science curriculum on minority student achievement, attitudes, and careers: The effects of teacher content and pedagogical content knowledge and inquiry-based practices. *Science Education*, *94*(5), 855–887. doi:10.1002/sce.20391

Kim, M., & Tan, A. L. (2011). Rethinking difficulties of teaching inquiry-based practical work: Stories from elementary pre-service teachers. *International Journal of Science Education*, *33*(4), 465–486.

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist*, *41*(2), 75–86.

Koch, J. (2006). Relating learning theories to pedagogy for preservice elementary science. In K. Appleton (Ed.), (2006). *Elementary science teacher education: International perspectives on contemporary issues and practice* (pp. 91–106). Mahwah, NJ: Lawrence Erlbaum.

Koksal, E. A., & Berberoglu, G. (2014). The effect of guided-inquiry instruction on 6th grade Turkish students' achievement, science process skills, and attitudes toward science. *International Journal of Science Education*, *36*(1), 66–78. doi:10.1080/09500693.2012.721942

Levitt, K. E. (2002). An analysis of elementary teachers' beliefs regarding the teaching and learning of science. *Science Education*, *86*(1), 1–22. doi:10.1002/sce.1042

McCoy, S., Smyth, E., & Banks, J. (2012). *The primary classroom: Insights from the growing up in Ireland study*. Dublin: ESRI.

McRobbie, C., & Tobin, K. (1997). A social constructivist perspective on learning environments. *International Journal of Science Education*, *19*(2), 193–208. doi:10.1080/0950069970190205

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook*. Beverly Hills, CA: Sage.

Mintzes, J. J., Marcum, B., Messerschmidt-Yates, C., & Mark, A. (2013). Enhancing self-efficacy in elementary science teaching with professional learning communities. *Journal of Science Teacher Education*, *24*(7), 1201–1218. doi:10.1007/s10972-012-9320-1

Monteiro, B., Martins, I., Souza, A., & Carvalho, F. (2016). The issue of the arrangement of new environments for science education through collaborative actions between schools, museums and science centres in the Brazilian context of teacher training. *Cultural Studies of Science Education*, 1–19. doi:10.1007/s11422-014-9638-4

Mulholland, J., & Wallace, J. (2003). Crossing borders: Learning and teaching primary science in the pre-service to in-service transition. *International Journal of Science Education*, *25*(7), 879–898.

National Science Foundation (NSF) (1998). Science policy seminar series. Retrieved from http://www.nsf.gov/news/speeches/colwell/rc80916.htm

Nichols, E. S., & Koballa, T. (2006). Framing issues of elementary science teacher education: Critical conversations. In K. Appleton (Ed.), *Elementary science teacher education: International perspectives on contemporary issues and practice* (pp. 107–124). Mahwah, NJ: Lawrence Erlbaum.

Ó Slatara, T., & Morgan, M. (2004). *The future of small schools and teaching principalship in Ireland*, Interim Report February 2004. Irish Primary Principals' Network, St Patrick's College.

Onwuegbuzie, A. J., & Collins, K. M. T. (2007). A typology of mixed methods sampling designs in social science research. *Qualitative Report*, *12*(2), 281–316.
Organisation for Economic Co-operation and Development (OECD) (2010). *Talis, teaching and learning international survey 2008 technical report*. Retrieved from http://www.oecd.org/edu/school/44978960.pdf
Osborne, J., & Dillon, J. (2008). *Science education in Europe: Critical reflections* (Vol. 13). London: The Nuffield Foundation.
Osborne, J., & Dillon, J. (2010). *Good practice in science teaching: What research has to say: What research has to say*. Columbus, OH: McGraw-Hill.
Pallant, J. (2010). *SPSS survival manual a step by step guide to data analysis using SPSS*. Maidenhead: Open University Press/McGraw-Hill. Retrieved from http://public.eblib.com/EBLPublic/PublicView.do?ptiID=744152
Palys, T. (2008). Purposive sampling. In L. M. Given (Eds.), *The Sage encyclopedia of qualitative research methods*. Los Angeles, CA: Sage.
Regan, E., & DeWitt, J. (2015). Attitudes, interest and factors influencing STEM enrolment behaviour: An overview of relevant literature. In Understanding *student participation and choice in science and technology education* (pp. 63–88). AZ Dordrecht: Springer.
Reid, B. (2011). The concept attainment strategy: Inductive lessons on arachnids and isomers. *The Science Teacher*, *78*(1), 51–55.
Ritchie, J., & Jane, L. (2003). *Qualitative research practice: A guide for social science students and researchers*. London: Sage.
Savasci, F., & Berlin, D. F. (2012). Science teacher beliefs and classroom practice related to constructivism in different school settings. *Journal of Science Teacher Education*, *23*(1), 65–86. doi:10.1007/s10972-011-9262-z
Schwab, J. J. (1963). *Biological sciences curriculum study: Biology teachers' handbook*. New York, NY: Wiley.
Science Foundation Ireland (SFI) (2014a). *Education and public engagement*. Retrieved from http://www.sfi.ie/discover-science-engineering-dse
Science Foundation Ireland (SFI) (2014b). *Three-year plan to deliver increase in uptake of science, technology, engineering and maths*. Retrieved from http://www.sfi.ie/news-resources/press-releases/three-year-plan-to-increase-in-uptake-of-stem.html and http://www.sfi.ie/assets/media/files/downloads/News%20and%20Events/Press%20Releases/Smart%20Futures%20Strategy%202014-16.pdf
Stocklmayer, S. M., Rennie, L. J., & Gilbert, J. K. (2010). The roles of the formal and informal sectors in the provision of effective science education. *Studies in Science Education*, *46*(1), 1–44.
Suchman, L. (1994). Working relations of technology production and use. *Computer Supported Cooperative Work*, *2*, 21–39.
Taba, H., & Spalding, W. B. (1962). *Curriculum development: Theory and practice*. New York: Harcourt, Brace and World.
Tan, E., Barton, A. C., Kang, H., & O'Neill, T. (2013). Desiring a career in STEM-related fields: How middle school girls articulate and negotiate identities-in-practice in science. *Journal of Research in Science Teaching*, *50*(10), 1143–1179. doi:10.1002/tea.21123
Teddlie, C., & Tashakkori, A. (Eds.). (2009). *Foundations of mixed methods research: Integrating quantitative and qualitative approaches in the social and behavioral sciences*. Thousand Oaks, CA: Sage.
Thomson, M. M., & Gregory, B. (2013). Elementary teachers' classroom practices and beliefs in relation to US science education reform: Reflections from within. *International Journal of Science Education*, *35*(11), 1800–1823.
Tillema, H. H., & Kremer-Hayon, L. (2002). "Practising what we preach" – teacher educators' dilemmas in promoting self-regulated learning: A cross case comparison. *Teaching and Teacher Education*, *18*(5), 593–607.
Tressel, G. W. (1994). Thirty years of "improvement" in precollege math and science education. *Journal of Science Education and Technology*, *3*(2), 77–88. doi:10.1007/BF01575187

Tytler, R., Osborne, J. F., Williams, G., Tytler, K., & Cripps Clark, J. (2008). *Opening up pathways: Engagement in STEM across the primary-secondary school transition*. Canberra: Australian Department of Education, Employment and Workplace Relations.

Varley, J., Murphy, C., & Veale, O. (2008). *Science in primary schools, Phase 1. Final report*. Bournemouth: NCCA.

Wenger, E. (1998). *Communities of practice, learning, meaning and identity*. Cambridge: Cambridge University Press.

Windschitl, M. (2002). Framing constructivism in practice as the negotiation of dilemmas: An analysis of the conceptual, pedagogical, cultural, and political challenges facing teachers. *Review of Educational Research*, *72*(2), 131–175. doi:10.3102/00346543072002131

Woods-Townsend, K., Christodoulou, A., Rietdijk, W., Byrne, J., Griffiths, J. B., & Grace, M. M. (2016). Meet the scientist: The value of short interactions between scientists and students. *International Journal of Science Education, Part B*, *6*(1), 89–113. doi:10.1080/21548455.2015.1016134

Yoon, H. G., & Kim, M. (2010). Collaborative reflection through dilemma cases of science practical work during practicum. *International Journal of Science Education*, *32*(3), 283–301. doi:10.1080/09500690802516538