

Children's aspirations and perceptions of science learning beyond the teacher-led

A dissertation submitted in fulfilment of the
requirements of the Degree of Doctor of Philosophy
at Trinity College Dublin, The University of Dublin

Lauren E. Boath

13314805

School of Education
Trinity College Dublin

Supervisor: Professor Colette Murphy

Submission: 25 June 2018

Award: 2019

Declaration

I hereby declare that this thesis has not been submitted as an exercise for the award of a degree at this or any other university and that it is entirely my own work. I agree to deposit this thesis in the University's open access institutional repository or allow the library to do so on my behalf, subject to Irish Copyright Legislation and Trinity College Library conditions of use and acknowledgement.

Lauren Boath

Date: 25 June 2018

Summary

Within this research study, a legally-robust children's rights-based methodology developed from the work of Lundy (2007) and Lundy and McEvoy (2011) was employed to explore children's perceptions of, and aspirations for, science learning beyond the teacher-led. Children as coresearchers and research participants (subjects) brought to the study expertise as children with contemporary experience in peer groups similar to 'people like them' (Murphy, Lundy, Emerson, & Kerr, 2013).

Children in a Scottish primary school formed a Children's Research Advisory Group (CRAG). The remit of the CRAG included: advising on how best to engage with other children on the issues being researched (Lundy & McEvoy, 2011); identifying themes to be explored within the research by providing insight on issues relating to the research questions; co-designing the research instrument (Murphy, Kerr, Lundy, & McEvoy, 2010); data analysis and evaluation; and reporting to research participants.

Almost 1100 children aged 8-14, in 13 primary and secondary schools across five Scottish local authorities, were involved in either piloting a questionnaire or as research participants. The questionnaire included closed questions and open-ended questions. Data analysis and evaluation included parametric and non-parametric testing using SPSS (IBM SPSS Statistics v22), StatPac (2017) and MedCalc (2017, 2018) software. Thematic analysis was carried out manually and using software including Microsoft Excel (2013) and NVivo (QSR International, v11).

This research study demonstrates that the children's rights-based methodology developed from the work of Lundy (2007) and Lundy and McEvoy (2011) can be employed successfully for a large-scale mixed-methods study relating to mainstream learning and teaching within the curriculum, in the Scottish context. An 'insider' view (Murphy, Mullaghy, & D'Arcy, 2016) leads to the content, language and design of the questionnaire being markedly different from those designed by adult researchers, resulting in high return rates and more robust data. This 'insider' view also provides insight in terms of understanding and interpreting responses and analysing and evaluating data. Children can engage as coresearchers, about matters beyond their lived experience, and demonstrate an understanding of the nuances and challenges of

research. I propose the children's rights-based methodology employed within the research as an operationalisation of Vygotsky's cultural historical theory (also known as sociocultural theory), through which zones of proximal development are created for children as coresearchers and research participants, adults as coresearchers and for the research itself.

Children within the study overwhelmingly reported liking learning science in school. This is the case for research participants in primary and secondary school, with the male-female 'gender gap' evident only in the strength of responses at age 13. Children who do not enjoy science learning beyond the teacher-led do not necessarily dislike learning science in school. As children progress from primary to secondary school, they continue to report liking learning science in school. However, their enjoyment of visiting places to do with science declines, as does the percentage of those reporting science experiences beyond the teacher-led as 'fun' or 'interesting'. The CRAG participants expressed an expectation that, for children in secondary school, science experiences should be 'more educational' and 'less fun'. However, the evidence of my research is that secondary school participants are not having 'more educational' science experiences beyond the teacher-led.

Whilst the majority of participants report finding science experiences fun, they do not consequently relate this to finding science fun. Fun is not an aspiration for science experiences for the majority of research participants. To a far greater extent, children are seeking the kind of enjoyment that comes from the challenge of learning, through interactivity and participation.

Two underlying constructs within children's science experiences were identified: external motivators relating to relevance, context and the wider world; internal motivators relating to fun, interest, curiosity and learning. The more positive children's self-perception of their science abilities, and the more they like learning science in school, the more likely they are to experience both the 'external motivators' and 'internal motivators' as a result of their science experiences. There is a sense of science experiences beyond the teacher-led 'preaching to the converted'.

Acknowledgements

There is a saying 'it takes a village to raise a child'. There should be a similar saying for the completion of a PhD and production of a thesis. I would like to thank my supervisor, Professor Colette Murphy. It began with a chance meeting in Paris, and I am grateful for her wisdom, support, guidance, challenge, inspiration and encouragement during this long journey. I would also like to thank Lesley Emerson and Professor Laura Lundy at Queen's University Belfast. It was a privilege to have the opportunity to meet with each of them to discuss my research and their perspectives, in meetings which informed and challenged my thinking. I am grateful to Paula Flynn at University College Dublin whose passion for children's voice and encouragement throughout made me feel that I had something to bring to this. Before the viva, I did not believe those who said I would enjoy the experience. However, my thanks go to my examiners Professor Michael Reiss of University College London, and Dr Joseph Roche of Trinity College Dublin. I very much enjoyed the challenge of the discussion and the opportunity to discuss my work and the enormous contribution made by the children as coresearchers and research participants.

It was a highlight of the PhD to work with and get to know the children in the Children's Research Advisory Group (CRAG). I am indebted to the children who formed the CRAG, who shaped, informed and advised on the research and the data, providing valuable insight, challenge and inspiration. I am thankful for the vision of the two Head Teachers and the class teacher at the school attended by the children of the CRAG, and the parents and carers who so enthusiastically embraced the opportunity for their children to be involved in research. This thesis would not have been possible without children sharing their thinking and ideas with me. I am very grateful to the almost 1100 children of whom gave up their time to participate in the pilot and research phases, to the Head Teachers of schools who agreed to share the invitation to participate with children, to staff in the primary and secondary schools who supported my fieldwork, and to Catharine Colvin for her role in supporting the CRAG's work.

There would not be a thesis without the help, support, encouragement and counselling of my parents, and friends and colleagues in Scotland and Ireland. They have generously provided everything from childcare, food supplies, hot water bottles, and

early morning and late-night lifts to and from airports, to IT support, driving me around schools to deliver and collect completed questionnaires, and giving up time to listen to (and question!) my thoughts on children's rights, science learning and Vygotsky. I am grateful for the support of Shane Bergin of University College Dublin, and colleagues at the University of Dundee, particularly Alexia Barrable, Maureen Kyle, David Porter, Jill Shimi and Neil Taylor, who read responses to open-ended questions, coded for the purposes of inter-rater reliability, reviewed sections of the thesis as it developed and were so supportive in difficult times. The pass at viva (without even minor corrections!) would have been impossible without their contributions and those of my fellow students at Trinity who put me through my paces with a mock viva. I have also very much valued working with the education students of the University of Dundee, undergraduate, postgraduate and qualified teachers. As I teach and learn with them, drawing on the knowledge and understanding developed through my research, their questions and challenge have caused me to reflect, to question and to deepen my own thinking. This has been one of the most enjoyable elements of the research and of my role as a teacher of teachers.

Most of all I would like to thank my husband, Iain, and our children, Grace and Oscar. The PhD journey had many highs and lows, including long periods of hospital, a period of maternity leave and the sleep deprivation of having a new baby. Without Iain's unfailing support through this journey and his ability to keep all the other plates spinning, I would not have been able to achieve this. Grace was 10 years old when I started this and will be 15 at the time of completion. Every day I feel proud and fortunate to be her mum; her determination, thoughtfulness and curiosity have both inspired and motivated me. She has kept me on track with her questions, comments and insight and has supported me throughout. And Oscar, who is my PhD baby and now is four years old: yes, mummy is putting the computer down now and coming to play.

Table of Contents

CHAPTER 1 INTRODUCTION 1

BACKGROUND AND RATIONALE FOR THE STUDY 1

RESEARCH AIMS AND QUESTIONS 3

STRUCTURE OF THE THESIS 3

CHAPTER 2 LITERATURE REVIEW 5

THE SCOTTISH CONTEXT: CURRICULUM FOR EXCELLENCE 5

LEARNING WHEREVER IT HAPPENS? 9

LEARNER VOICE 40

A THEORETICAL FRAMEWORK FOR EXPLORING CHILDREN’S EXPERIENCES AND PERCEPTIONS OF

LEARNING SCIENCE BEYOND THE TEACHER-LED..... 46

CHAPTER 3 METHODOLOGY 61

INTRODUCTION 61

TERMS USED IN THIS RESEARCH STUDY 61

RESEARCH AIM AND QUESTIONS..... 63

RESEARCH PARADIGM 63

ETHICS..... 65

RESEARCH DESIGN AND APPROACH..... 69

RESEARCH INSTRUMENTS..... 88

DATA COLLECTION..... 93

DATA ANALYSIS AND EVALUATION 101

CHAPTER 4 FINDINGS AND DISCUSSION: LEARNER AT THE CENTRE 123

CREATING ZPDs FOR CRAG PARTICIPANTS..... 123

CREATING ZPDs FOR RESEARCH PARTICIPANTS 149

CHILDREN’S RIGHTS-BASED METHODOLOGY AS AN ENACTMENT OF CHT 160

THE ‘LEARNER AT THE CENTRE’ THROUGH A CHILDREN’S RIGHTS-BASED METHODOLOGY 162

CHAPTER 5 FINDINGS AND DISCUSSION: CHALLENGE AND ENJOYMENT..... 169

DO CHILDREN LIKE LEARNING SCIENCE IN SCHOOL?	170
WHO IS HAVING SCIENCE EXPERIENCES, AND WITH WHOM?	179
CHILDREN'S ASPIRATIONS AND THE REALITY OF THEIR EXPERIENCES	182
UNDERSTANDING SCIENCE LEARNING BEYOND THE TEACHER-LED THROUGH A CHILDREN'S RIGHTS- BASED METHODOLOGY.....	210

CHAPTER 6 DISCUSSION: LEARNING SCIENCE IN SCOTLAND AND CHILDREN'S VOICE 217

WE NEED EXPERTS...DID WE ASK THE CHILDREN?.....	220
CHILDREN ARE NOT ALL THE SAME, AND NEITHER ARE THEIR SCIENCE EXPERIENCES.....	227
THE ROLE OF INFORMAL SCIENCE LEARNING PROVIDERS.....	234
CHILDREN'S ASPIRATIONS FOR SCIENCE EXPERIENCES, IN THE CONTEXT OF CfE	238

CHAPTER 7 CONCLUSION..... 241

THE THESIS	242
LIMITATIONS AND OPPORTUNITIES.....	245
THE PERSONAL JOURNEY TO AND THROUGH DOCTORAL RESEARCH	247
FUTURE RESEARCH	249

List of Acronyms

BtC	Building the Curriculum
CfE	Curriculum for Excellence
Crag	Children’s Research Advisory Group
CRC	Convention on the Rights of the Child
DBIS	Department for Business Innovation and Skills
DfE	Department for Education
DfES	Department for Education and Skills
DSC	Dundee Science Centre
ES	Education Scotland
GSC	Glasgow Science Centre
GTCS	General Teaching Council for Scotland
HMIE	Her Majesty’s Inspectorate of Education
LTS	Learning and Teaching Scotland
MKO	More knowledgeable other
OECD	Organisation for Economic Co-operation and Development
PCA	Principal component analysis
PKC	Perth and Kinross Council
PVG	Protecting Vulnerable Groups
SCQF	Scottish Credit and Qualifications Framework
SE	Scottish Executive
SEEAG	Science and Engineering Education Advisory Group
SES	Socio-economic status
SG	Scottish Government
SOED	Scottish Office Education Department
SSAC	Scottish Science Advisory Council
SSCN	Scottish Science Centres Network
STEM	Science, technology, engineering and mathematics
STEMEC	STEM Education Committee
UK	United Kingdom
UN	United Nations
UNCRC	United Nations Convention on the Rights of the Child
USA	United States of America
ZPD	Zone of Proximal Development
*	Significant at the $p = 0.05$ level
**	Significant at the $p = 0.01$ level
***	Significant at the $p = 0.001$ level

List of Figures

FIGURE 2.1 THE CONTINUUM OF FORMAL, NON-FORMAL AND INFORMAL LEARNING	13
FIGURE 2.2 THE FOUR FACTORS – SPACE, VOICE, AUDIENCE, INFLUENCE – AND THEIR RELATIONSHIP WITH THE MAIN STRANDS OF ARTICLE 12 AND OTHER RELEVANT UNCRC PROVISIONS.....	55
FIGURE 2.3 ASSISTING CHILDREN TO AN (IN)FORMED VIEW.....	57
FIGURE 3.1 SUMMARY OF CRAG INVOLVEMENT IN THE RESEARCH PROCESS INCLUDED IN INFORMATION LEAFLET FOR PARENTS AND CARERS, AND SCHOOL STAFF.....	66
FIGURE 3.2 FORMAT FOR CRAG TO SUGGEST RESPONSES TO ASSIST RESEARCH PARTICIPANTS TO INFORMED VIEWS (QUESTIONNAIRE VERSION 4 OF 11)	92
FIGURE 3.3 NOTE FROM SCHOOL INCLUDED WITH COMPLETED QUESTIONNAIRES	96
FIGURE 3.4 GEOGRAPHICAL SPREAD OF SCHOOLS THROUGH WHICH INVITATION TO PARTICIPATE DISTRIBUTED.....	98
FIGURE 3.5 AGE OF RESEARCH PARTICIPANTS.....	99
FIGURE 3.6 AGE AND GENDER OF RESEARCH PARTICIPANTS	100
FIGURE 3.7 QUESTION 4 FROM FINAL QUESTIONNAIRE.....	106
FIGURE 3.8 PCA SCREE PLOT ON QUESTION 4 RESPONSES (EIGENVALUES > 1.0, VALUES < 0.3 SUPPRESSED)	108
FIGURE 3.9 PCA SCREE PLOT ON QUESTION 4 RESPONSES (EIGENVALUES > 1.0, VALUES < 0.5 SUPPRESSED)	112
FIGURE 3.10 EXAMPLE OF PARTICIPANTS' RESPONSES TRANSFERRED TO INDIVIDUAL SLIPS OF PAPER FOR CRAG PARTICIPANTS' CONSIDERATION.....	115
FIGURE 4.1 EXTRACT (QUESTION 4) FROM QUESTIONNAIRE VERSION 4.....	129
FIGURE 4.2 EXTRACT (QUESTION 4) FROM QUESTIONNAIRE VERSION 5	129
FIGURE 4.3 EXTRACT (QUESTION 4) FROM QUESTIONNAIRE VERSION 11	130
FIGURE 4.4 EXTRACT (QUESTION 8) FROM QUESTIONNAIRE VERSION 4.....	131
FIGURE 4.5 EXTRACT (QUESTION 8) FROM QUESTIONNAIRE VERSION 11	131
FIGURE 4.6 BAR CHARTS USED BY CRAG TO DISCUSS RESPONSES TO QUESTION 4 ABOUT SCIENCE EXPERIENCES	133
FIGURE 4.7 USE OF BAR CHARTS OF QUESTIONNAIRE RESPONSES TO DISCUSS AND PREDICT OUTCOMES.....	134
FIGURE 4.8 EXAMPLE OF APPROACHES TO EVALUATION WITH CRAG	135
FIGURE 4.9 EXAMPLE OF APPROACHES TO EVALUATION WITH CRAG	137
FIGURE 4.10 FIELD NOTES OF CRAG MEETING 8.....	140
FIGURE 4.11 CHILDREN'S REFLECTIONS ON CRAG PARTICIPATION	141
FIGURE 4.12 CHILDREN'S REFLECTIONS ON CRAG PARTICIPATION: A STILL FROM THE VIDEO 'CRAG EXPERIENCE'	142

FIGURE 4.13 CHILDREN'S REFLECTIONS ON CRAG PARTICIPATION: A STILL FROM THE VIDEO 'CRAG IS FAB'	143
FIGURE 4.14 VISUALISATION OF THE CREATION OF ZPDS THROUGH CHILDREN'S RIGHTS-BASED METHODOLOGY	146
FIGURE 4.15 3D VISUALISATION OF THE TWO-WAY INTERACTION BETWEEN CRAG PARTICIPATION AND CREATION OF ZPDS FOR CRAG PARTICIPANTS	147
FIGURE 4.16 3D VISUALISATION OF THE TWO-WAY INTERACTION BETWEEN CRAG PARTICIPATION AND CREATION OF ZPDS FOR RESEARCHER AND RESEARCH ¹⁴	148
FIGURE 4.17 EXTRACT FROM QUESTIONNAIRE (QUESTION 5)	150
FIGURE 4.18 EXTRACT FROM QUESTIONNAIRE (QUESTION 5)	153
FIGURE 4.19 EXTRACT FROM QUESTIONNAIRE (QUESTION 6)	154
FIGURE 4.20 RESPONSES TO OPEN-ENDED QUESTIONS BY PRIMARY-SECONDARY SECTOR ...	157
FIGURE 4.21 EXTRACT FROM QUESTIONNAIRE (QUESTION 7)	159
FIGURE 4.22 VISUALISATION OF THE CHILDREN'S RIGHTS-BASED METHODOLOGY AS AN ENACTMENT OF CHT	161
FIGURE 4.23 3D VISUALISATION OF A LIMITED EXPERIENCE TWO-WAY INTERACTION BETWEEN CRAG PARTICIPATION AND CREATION OF ZPDS FOR RESEARCHER AND RESEARCH ¹⁴	165
FIGURE 5.1 PROMPT QUESTIONS FOR CRAG DISCUSSION OF QUESTIONNAIRE DATA, AS PRESENTED TO THE CRAG PARTICIPANTS	176
FIGURE 5.2 NVIVO CREATED CLOUD OF WORDS (N = 150 UNIQUE WORDS) APPEARING IN RESPONSES TO "HOW CAN SCIENCE EXPERIENCES HELP YOU LEARN?" WHICH INCLUDE THE WORD FUN	187
FIGURE 5.3 NVIVO CREATED CLOUD OF WORDS (N = 190 UNIQUE WORDS) APPEARING IN RESPONSES TO "HOW CAN SCIENCE EXPERIENCES HELP YOU ENJOY SCIENCE?" WHICH INCLUDE THE WORD FUN	187
FIGURE 5.4 NVIVO CREATED CLOUD OF MOST FREQUENT WORDS APPEARING IN RESPONSES (N = 369) TO "HOW CAN SCIENCE EXPERIENCES HELP YOU LEARN?" RELATING TO INTERACTIVITY	196
FIGURE 5.5 NVIVO CREATED CLOUD OF MOST FREQUENT WORDS APPEARING IN RESPONSES (N = 454) TO "HOW CAN SCIENCE EXPERIENCES HELP YOU ENJOY SCIENCE MORE?" RELATING TO INTERACTIVITY	196
FIGURE 6.1 VISUALISATION OF THE CREATION OF ZPDS THROUGH PARTICIPATION IN A CHILDREN'S LEARNING ADVISORY GROUP	226

List of Tables

TABLE 2.1 DEFINITIONS OF FORMAL, INFORMAL AND NON-FORMAL LEARNING	11
TABLE 2.2 PERCENTAGE OF PARTICIPANTS WHO AGREED OR STRONGLY AGREED WITH LEARNING OUTCOME STATEMENTS IN FINAL VISITOR RESEARCH REPORT 2008-10: SCOTTISH SCIENCE CENTRE EVALUATION	38
TABLE 3.1 TERMS USED IN LITERATURE RELATING TO LEARNING SCIENCE	61
TABLE 3.2 TERMS USED IN THIS STUDY.....	62
TABLE 3.3 METHODS OF IDENTIFYING PARTICIPATING PRIMARY SCHOOLS	95
TABLE 3.4 METHODS OF IDENTIFYING PARTICIPATING SECONDARY SCHOOLS	97
TABLE 3.5 PRIMARY-SECONDARY SECTOR BREAKDOWN OF QUESTIONNAIRE RETURNS	98
TABLE 3.6 GENDER AND SECTOR BREAKDOWN OF PARTICIPANTS	99
TABLE 3.7 ITEMS WITH SIGNIFICANT DIFFERENCES IN RESPONSE RATES BETWEEN DIFFERENT GROUPINGS	101
TABLE 3.8 CORRELATION BETWEEN PERCEPTION OF BEING GOOD AT SCIENCE AND OTHER RESPONSES FROM PARTICIPANTS (PEARSON PRODUCT-MOMENT)	104
TABLE 3.9 CORRELATION BETWEEN PERCEPTION OF BEING GOOD AT SCIENCE AND OTHER RESPONSES FROM PARTICIPANTS (SPEARMAN'S RHO)	105
TABLE 3.10 PCA ON QUESTION 4 RESPONSES.....	107
TABLE 3.11 PCA ON QUESTION 4 RESPONSES (EIGENVALUES > 1.0, VALUES < 0.3 SUPPRESSED): TOTAL VARIANCE EXPLAINED	109
TABLE 3.12 FACTOR LOADINGS (PATTERN MATRIX) BASED ON PCA WITH OBLIMIN ROTATION FOR 13 ITEMS WITHIN QUESTION 4 (EIGENVALUES > 1.0, SUPPRESS VALUES < 0.3)	110
TABLE 3.13 FACTOR LOADINGS (PATTERN MATRIX) BASED ON PCA WITH OBLIMIN ROTATION FOR 13 STATEMENTS WITHIN QUESTION 4 (EIGENVALUES > 1.0, SUPPRESS VALUES < 0.5)	111
TABLE 4.1 PRIMARY-SCHOOL PARTICIPANTS' RESPONSES TO STATEMENTS "MY SCIENCE EXPERIENCE..." WITH CRAG PREDICTIONS	136
TABLE 4.2 WORD COUNT AND WORD LENGTH IN OPEN-ENDED QUESTION RESPONSES.....	154
TABLE 4.3 RESPONSE RATES FOR OPEN-ENDED QUESTIONS.....	155
TABLE 4.4 GENDER BREAKDOWN OF RESPONSE RATES TO OPEN-ENDED QUESTIONS	156
TABLE 4.5 PRIMARY-SECONDARY SECTOR BREAKDOWN OF RESPONSES TO OPEN-ENDED QUESTIONS.....	157
TABLE 5.1 PERCENTAGE OF PARTICIPANTS WHO REPORTED THAT THEY LIKE LEARNING SCIENCE IN SCHOOL.....	170
TABLE 5.2 COMPARISON OF MEANS CALCULATED FROM RESPONSES TO QUESTION ON LIKING LEARNING SCIENCE IN SCHOOL.....	171

TABLE 5.3 GENDER BREAKDOWN OF MEAN NUMBER OF SCIENCE ACTIVITIES ENJOYED AT AGE 13	171
TABLE 5.4 MEAN NUMBER OF SCIENCE ACTIVITIES ENJOYED BY THOSE WHO DO AND DO NOT LIKE LEARNING SCIENCE IN SCHOOL	177
TABLE 5.5 PARTICIPANTS WHO REPORTED POSITIVE FEELINGS ABOUT SCIENCE	178
TABLE 5.6 PRIMARY-SECONDARY SECTOR BREAKDOWN OF SCIENCE EXPERIENCES WITH SCHOOL, WITH FAMILY OR FRIENDS ONLY, BOTH WITH SCHOOL AND WITH FAMILY OR FRIENDS.....	179
TABLE 5.7 PRIMARY-SECONDARY SECTOR BREAKDOWN OF SCIENCE EXPERIENCES WITH SCHOOL	179
TABLE 5.8 PRIMARY-SECONDARY SECTOR BREAKDOWN OF MEAN NUMBER OF SCIENCE ACTIVITIES ENJOYED.....	180
TABLE 5.9 PRIMARY-SECONDARY SECTOR BREAKDOWN OF SCIENCE EXPERIENCES WITH FAMILY OR FRIENDS	180
TABLE 5.10 SCIENCE EXPERIENCES WITH SCHOOL ONLY.....	181
TABLE 5.11 PRIMARY-SECONDARY SECTOR BREAKDOWN OF SCIENCE ACTIVITIES ENJOYED..	182
TABLE 5.12 PRIMARY-SECONDARY SECTOR AND GENDER BREAKDOWN OF ENJOYMENT OF VISITING PLACES TO DO WITH SCIENCE	183
TABLE 5.13 PRIMARY-SECONDARY SECTOR BREAKDOWN OF FINDING SCIENCE EXPERIENCES FUN AND INTERESTING	183
TABLE 5.14 PRIMARY-SECONDARY SECTOR BREAKDOWN OF INDICATORS OF FINDING SCIENCE EXPERIENCES 'EDUCATIONAL'	185
TABLE 5.15 RESPONSES TO OPEN-ENDED QUESTIONS FEATURING THE WORD "FUN"	186
TABLE 5.16 RESPONSES TO OPEN-ENDED QUESTIONS FEATURING INTERACTIVITY AND PARTICIPATION	188
TABLE 5.17 RESPONSES TO OPEN-ENDED QUESTIONS RELATING TO EXPERIMENTS.....	190
TABLE 5.18 ENJOYMENT OF DOING EXPERIMENTS WITH KITS BY PERCEPTION OF SCIENCE ABILITY	191
TABLE 5.19 ENJOYMENT OF VISITING PLACES TO DO WITH SCIENCE BY PERCEPTION OF SCIENCE ABILITY	191
TABLE 5.20 RESPONSES TO OPEN-ENDED QUESTIONS RELATING TO TECHNOLOGIES	195
TABLE 5.21 FINDING SCIENCE EXPERIENCES FUN AND INTERESTING BY PERCEPTION OF SCIENCE ABILITY	200
TABLE 5.22 EXPERIENCE OF 'INTERNAL MOTIVATORS' BY PERCEPTION OF SCIENCE ABILITY .	202
TABLE 5.23 RESPONSES TO OPEN-ENDED QUESTIONS RELATING TO CHALLENGE AND PURPOSE	203

TABLE 5.24 PARTICIPANTS' LIKING OF LEARNING SCIENCE IN SCHOOL AND THEIR SCIENCE EXPERIENCES (FUTURES AND JOBS)	206
TABLE 5.25 EXPERIENCE OF 'EXTERNAL MOTIVATORS' BY PERCEPTION OF SCIENCE ABILITY .	207
TABLE 5.26 EXPERIENCE OF 'EXTERNAL MOTIVATORS' BY LIKING OF LEARNING SCIENCE IN SCHOOL	208
TABLE 5.27 EXPERIENCE OF 'INTERNAL MOTIVATORS' BY LIKING OF LEARNING SCIENCE IN SCHOOL	209

List of Appendices

APPENDIX 1 EXTRACT FROM SCHEMATIC GUIDE TO CURRICULUM FRAMEWORK FOR CURRICULUM PLANNERS.....	289
APPENDIX 2 RECORD OF PVG SCHEME MEMBERSHIP	291
APPENDIX 3 APPLICATION TO UNDERTAKE RESEARCH IN PKC EDUCATION & CHILDREN'S SERVICES.....	293
APPENDIX 4 INFORMATION LEAFLETS AND CONSENT FORMS.....	295
APPENDIX 5 PROFILE OF THE PRIMARY SCHOOL HOSTING THE CRAG	301
APPENDIX 6 SCHEDULE OF CRAG MEETINGS	303
APPENDIX 7 CRAG BADGES	305
APPENDIX 8 CRAG BADGES (UPDATED)	307
APPENDIX 9 ACTIVITIES TO ENABLE ACCESS TO INFORMATION TO INFORM VIEWS	309
APPENDIX 10 TRANSCRIPT OF INTRODUCTORY VIDEO FOR RESEARCH PARTICIPANTS	317
APPENDIX 11 QUESTIONNAIRE ISSUED FOR USE WITH RESEARCH PARTICIPANTS (VERSION 11)	319
APPENDIX 12 REVIEWING RESEARCH INSTRUMENTS (CRAG MEETING 2).....	321
APPENDIX 13 EXTRACTS FROM CRAG DISCUSSION ON QUESTIONNAIRE DEVELOPMENT	323
APPENDIX 14 CRAG RESPONSES TO TRIAL QUESTIONNAIRES (ANNOTATED)	327
APPENDIX 15 E-MAIL CORRESPONDENCE WITH PRIMARY SCHOOL RE QUESTIONNAIRE PILOT	329
APPENDIX 16 QUESTIONNAIRE VERSION 6 FOR PILOT	331
APPENDIX 17 SCHOOLS (PRIMARY) CONTACTED FOR QUESTIONNAIRE DISTRIBUTION	333
APPENDIX 18 COMMUNICATION WITH HEAD TEACHERS IN RESPECT OF INVITATION TO PARTICIPATE	335
APPENDIX 19 SCHOOLS (SECONDARY) CONTACTED FOR QUESTIONNAIRE DISTRIBUTION	337
APPENDIX 20 SIGNIFICANT CORRELATIONS (SPEARMAN'S RHO)	339
APPENDIX 21 EXAMPLES OF DEMOGRAPHIC DATA VISUALISATION FOR CRAG.....	343
APPENDIX 22 DATA VISUALISATIONS OF RESPONSES TO QUESTION "WHO WAS YOUR SCIENCE EXPERIENCE WITH?"	345
APPENDIX 23 VISUALISATIONS OF PARTICIPANT RESPONSES TO QUESTION "HOW CAN SCIENCE EXPERIENCES HELP YOU LEARN?"	347
APPENDIX 24 VISUALISATIONS OF PARTICIPANT RESPONSES TO QUESTION "HOW DO SCIENCE EXPERIENCES MAKE YOU FEEL ABOUT SCIENCE?"	351
APPENDIX 25 EXTRACTS OF TRANSCRIPT OF CRAG MEETING 8	353
APPENDIX 26 DATA RELATING TO RESPONSES TO QUESTIONNAIRE QUESTION "DO YOU LIKE LEARNING SCIENCE IN SCHOOL?"	361
APPENDIX 27 RESPONSES TO QUESTION 4 "MY SCIENCE EXPERIENCE..."	363

Chapter 1 Introduction

In chapter one, the aim of this research study and the research questions are introduced. A brief discussion is included justifying the need for this study and outlining the particular circumstances and events which coincided internationally and in Scotland specifically, to provide the stimulus for this work.

Background and rationale for the study

Aim

The aim of this study is to explore children's experiences of learning science beyond the teacher-led, and their perceptions of these experiences. This research focuses on 'science experiences': science or science-related activities other than those which are part of structured, teacher-led learning and teaching in the school setting. 'Science experiences' can include, but are not limited to, activities which take place in the school setting, where these are led by external adults¹. This research does not define for, or dictate to, children what a 'science experience' is; these are identified by the participants from their own perspectives.

The significance of this study

The research presented within this thesis is timely. Internationally, there is a growing awareness of the importance of what can be broadly termed 'informal science learning', beyond structured, teacher-led 'formal' science learning within schools (see, for example, P. Bell, Lewenstein, Shouse, & Feder, 2009; Dillon, 2013). Within the literature review, I explore several of the drivers for this increasing interest in science experiences.

It is only recently that the informal sector has been recognised as having a role to play in education (Stocklmayer, Rennie, & Gilbert, 2010). With this comes growing recognition of the need to better understand what is happening in informal science

¹ Examples of such provision includes STEM Ambassadors, staff from higher education institutions, and outreach activities by science festivals and science centres through providers such as: Edinburgh International Science Festival (2015); (GSC, 2015); STEMNET (2015); Universities Scotland (2013).

learning and to identify potential synergies between learning in school and out of school. Internationally, since 1980, there has been a steady increase in research publications about informal learning in science (Falk et al., 2012). However, in this relatively young field (Baram-Tsabari & Osborne, 2015), much of this research is descriptive (Falk et al., 2012). Following a review of the contribution of informal science-learning providers in the UK in 2012, the Wellcome Trust launched the *Science Learning +* initiative (2012). This initiative offered funding of up to £7.5 million for projects in the UK, Ireland and USA that developed understanding of “the power” (Wellcome Trust, 2012) of informal science-learning experiences, in and out of school. The funding commitment is particularly significant in a sector in which there is little funding for research and development (Stocklmayer et al., 2010), and in which it is only in the last few years that there has been any large-scale effort to explore science learning beyond the teacher-led, particularly in the UK. The work described within this thesis contributes to the knowledge in this field.

The aspect of my research which examines and develops a methodology for accessing children’s voice, exploring children’s perspectives through involvement as coresearchers and research subjects, is also timely. Methods which engage children’s voice and perspectives are notably absent from much of the research into understanding science learning (see, for example, Buntting, Gunstone, Corrigan, Dillon, & Jones, 2015). Children as coresearchers and research subjects bring to my study expertise as children with contemporary experience in peer groups similar to ‘people like them’ (Murphy et al., 2013). This overtly children’s rights-based methodology, using a legally-sound but workable model for implementing Article 12 of the *United Nations Convention on the Rights of the Child (UNCRC)* (1989), moves children’s participation and ‘voice’ from a moral imperative to a legal one (Lundy & Cook-Sather, 2015). It provides an opportunity to explore science learning beyond the teacher-led in a depth currently absent from research and reports in a field in which children’s rights are currently “ignored or underplayed” (Lundy, 2007, p. 928) and children’s perceptions absent (Falk et al., 2012). Synergies between science-learning opportunities wherever they happen are more likely to be evident and identified where the approach is not only top-down, but also bottom-up, incorporating not only those on the “delivery end” but also those on the “receiving end” (Falk et al., 2015, p. 165).

Understanding science learning beyond the teacher-led

The challenges in understanding science learning beyond the teacher-led are not insignificant. With opportunities for learning science beyond school dependent on private and public funding linked to ‘educational’ outcomes (Rennie, 2014) it is unsurprising, inevitable, that there is a focus on categorising and labelling opportunities for learning, and on measuring and quantifying retrospectively to evidence that learning has occurred. My study addresses a significant gap in the field by exploring proactively, from the perspective of children, what science experiences beyond the teacher-led can do to help children learn science and enjoy science more.

Research aims and questions

Within this study, the following questions are addressed:

- what are children’s perceptions of science experiences, beyond those which are teacher-led?
- what do children think science experiences could do to help them learn and enjoy science more?

Structure of the thesis

This introductory chapter sets out the rationale for the study. Chapter two examines the internationally-acknowledged complexity of the challenge in understanding the science experiences of children and exploring children’s experiences and perceptions of science learning beyond the teacher-led. In chapter two, I draw together relevant literature relating to learning and learning science, in-school and out-of-school, broadly termed ‘formal’ and ‘informal’ learning.

Research with children presents different challenges from research with adults and requires appropriate tools and approaches. I address the literature relating to listening to children’s voice, with a focus on approaches which are explicitly rights-compliant. This is particularly relevant in the Scottish context; the curriculum designed with the

learner at the centre (ES, n.d.-b) requires an understanding of, and approaches framed by, the rights of the child. The research described within this thesis is framed by Vygotsky's theory of the "nature and development of the human mind" (Yudina, 2007, p. 3), cultural-historical theory, which has a grounding both in theory and in practice (Yudina, 2007). Thus, there is an exploration of key literature relating to Vygotsky's work, in particular the zone of proximal development (ZPD).

In chapter three, I describe my use of a children's rights-based approach to participation in research, drawing on a legally-robust approach to participatory research compliant with the *UNCRC* (Lundy, 2007; Lundy & McEvoy, 2011, 2012) and in particular building on its application in research exploring children's perceptions of primary science assessment (Murphy et al., 2010; Murphy et al., 2013).

In chapter four I explore and discuss my findings with respect to the learner at the centre of the experience, and in chapter five, children's aspirations and their perceptions of the realities of their science experiences. Chapter six comprises overarching discussion. Finally, chapter seven suggests areas for further exploration arising from my research and concludes the thesis.

The overarching principles of Scotland's current curriculum for 3 to 18 year olds, *Curriculum for Excellence (CfE)* (Scottish Executive, 2004a, 2004b), were developed from 2004 onwards, with implementation formally mandated in 2010/11 (Priestley & Minty, 2013). CfE was developed in response to a rapidly-changing world, and the rapidly-changing expectations of education and children's learning. I have therefore primarily focused my literature review on temporally-relevant research, published since 2000.

Chapter 2 Literature Review

Within this literature review, the thesis is framed within the Scottish context. Key issues around learning in formal and informal contexts, with a focus on learning science, and participatory research with children are examined.

In outlining the Scottish context, I focus on the development and implementation of CfE and the impact of this on the landscape of science learning. In particular, I examine the introduction of the idea that the curriculum encompasses not only what happens in schools, and teacher-led learning, but also learning wherever it happens, including that experienced through partner organisations and external bodies. I track the integration of this shift in definition of the curriculum into policy to be enacted by teachers and schools, and into criteria for inspection in schools and professional standards for teachers.

The Scottish Context: Curriculum for Excellence

Defining the curriculum

CfE, envisaged as a forward looking, coherent, challenging curriculum for 3 to 18-year olds across Scotland, was mandated for implementation in 2010/2011 (Priestley & Minty, 2013). By June 2016, initial implementation from early years, in early learning and childcare settings, to S6, the final year in secondary school, was completed.

Following the publication in 2004 of *A Curriculum for Excellence* (SE, 2004b), a process of significant curriculum reform began in Scotland. *A Curriculum for Excellence* (SE, 2004b) outlined the purposes and principles of education and the curriculum for 3 to 18 year olds, reflecting educational research, albeit somewhat limited (Humes, 2013), international comparisons and views expressed during a *National Debate on Education* (SE, 2002). The intention of the *National Debate* was to create a vision for Scottish education. However, the surrounding narrative directed discussion and thinking towards minor change to existing structures and approaches, with no explicit encouragement to think more widely about the future of children's learning in Scotland. It might therefore have been anticipated, or indeed have been inevitable, that any

future vision for Scotland would not depart significantly from the existing '5-14' curriculum guidelines concerned with the education of children aged 5 to 14 years (SOED, 1993). Participants in the *National Debate* were directed to consider the 'when?' and 'where?' of Scottish education. 'When?' was exclusively associated with the logistics of school learning: school starting and leaving age; timing and length of holidays; the school day (SE, 2002). 'Where?' included consideration of school design and use, and arrangements for travelling to and from school (SE, 2002). There was no suggestion of any broader interpretation to include learning taking place other than in the school setting or to acknowledge that learning happens beyond the classroom.

The scope of the *National Debate* may have missed an opportunity to consider learning in a wider context or in settings other than schools. However, a review group subsequently appointed by the Scottish Executive did not. The group, charged with identifying the purposes of education and the principles of the curriculum for 3 to 18 year olds, introduced a broader interpretation of the curriculum:

A Curriculum for Excellence...applies to the experiences provided in the **different places** where they [all children and young people] go to learn...and **others working in partnership with schools**. It recognises the wide range of educators working in these sectors. Because children learn through all of their experiences – **in the family and community...the curriculum needs to recognise and complement the contributions that these experiences can make**. [emphases added]

(SE, 2004b, p. 9)

In many aspects, CfE has more in common with the 5-14 curriculum guidelines (Adams, 1997) which it replaced than the idea of 'visionary reform' might suggest (Priestley & Biesta, 2013). This might be expected given the narrative surrounding the *National Debate*. However, the definition of the curriculum represents a paradigm shift and the most significant departure from the previous curriculum guidelines. The 5-14 guidelines make no mention of learning in any setting other than the classroom and school and focus the 'wider curriculum' on the school experience, and the values and priorities of the school (SOED, 1993). Within CfE, the curriculum is described as more than learning led by teachers in schools, as the "totality of experiences which are planned for children

and young people throughout their education, wherever they are being educated” (SG, 2008, p. 11).

Implementation: accountability, inspection and professional standards

In general, implementation is a problematic aspect of curriculum reform in Scotland and tensions exist between policy and practice (Priestley, 2010; Priestley, Minty, & Eager, 2014). The redefinition of the curriculum to include learning with partners particularly suffers from what Supovitz (2008) describes as the “implementation gap – the problematic issue of translation from prescribed policy to enacted practice” (Supovitz, 2008, cited in Priestley, 2010, p. 25). Teachers, schools and education authorities interpret flexible policy frameworks, translating and enacting these in classrooms, with the expectation that they make use of that flexibility to design creative learning programmes, raising achievement and attainment for all (Priestley, 2010; SE, 2004a; SE, 2004b).

The importance of the contribution of partners to children’s learning within the curriculum has been increasingly widely expressed in documents intended to inform and influence the planning of learning and teaching by teachers, schools and education authorities (see, for example, ES, 2012; SE, 2004b). A Scotland-wide review of implementation of CfE in sciences encouraged enrichment and enhancement of school-based learning through the use of science initiatives and partnership working with external providers as **part of the curriculum** and in a way which contributes to progression of learning for children (ES, 2012, 2013b). In the review, science learning that is supported by numerous external partners was identified as good practice with particular mention of the four national science centres and the STEM Ambassador scheme (ES, 2012, 2013b). The need for schools to plan with partners to add value in science learning was emphasised, and it was noted that external partners are increasingly linking offerings to the curriculum experiences and outcomes to enable planning for coherent, relevant, meaningful learning (ES, 2013b). And yet, in science, it is unclear to what extent external partners and organisations have an understanding of CfE and how to contribute effectively to progression of learning (Falk et al., 2012).

A system of school inspection is used in Scotland to hold education authorities, schools and teachers accountable for the decisions made in respect of curriculum design and implementation (Priestley, 2010). The expectation in relation to the curriculum in advice on inspection procedures and processes, cements the redefinition of the curriculum:

The curriculum is defined as the totality of learning experienced, irrespective of where the learning takes place. This includes learning **in and out of school and that delivered through partnerships** [emphasis added]. (ES, 2015, p. 3)

The drive to include partner inputs in planned learning and teaching is not limited to policy documents and inspection procedures. Partnership working features throughout the professional standards for teachers and education leaders in Scotland, with teachers encouraged to “recognise and encourage the wide and diverse range of partnerships which contribute to the learning...draw upon knowledge and expertise from other professional partners to enhance programmes for learners...collaborate with partners to facilitate access to appropriate learning opportunities and resources” (GTCS, 2012a, pp. 15, 21).

Despite the policy demands and mechanisms for accountability, there is little evidence on which those charged with planning learning with partners can build, or evidence that partners and external organisations are in a position to support “coherent, relevant and meaningful learning” (ES, 2013b, p. 12). This is perhaps reflective of a wider issue in Scottish education, summarised by one of the ‘architects’ of CfE: “Scotland tends not to be short of worthwhile ideas. What it lacks is effective means of putting them in practice.” (Bloomer, in Freeman, 2015).

Learning wherever it happens?

In this section, I consider issues and debates associated with learning science in and out of school, examining and analysing literature relating to learning in informal, non-formal and formal contexts, internationally and in the UK. In Scotland, the emphasis through policy and guidance is on partnership working to enhance science **learning**, not simply **experiencing** science. I explore the evidence and research available to understand the contribution of learning beyond the teacher-led, and the extent of evidence available on which to base informed decisions about integrating out-of-school science learning into planned learning and teaching in science.

From formal to free-choice learning

There is increasing global interest in the opportunities for learning informally or in everyday life as a source of human capital, and increasing recognition of such learning as a route into formal learning (Werquin, 2010). The idea that learning happens beyond schools, that there is no single way or place in which we learn, is not a new one (Falk & Dierking, 2002; Kisiel, 2003; Resnick, 1987). Regardless, society still considers school as the main, or indeed sole, site of learning (Bybee, 2001; Osborne & Dillon, 2007). Contrasting sharply with parallel developments in education in England, where the curriculum is much more narrowly defined as “the programmes of study and attainment for all subjects” (DfE, 2013, section 1.1), recent curriculum reform in Scotland radically redefines the curriculum to recognise learning wherever it happens (ES, 2015; SG, 2008). Developments in Scotland align more closely with the USA where the limitations of the classroom environment for science learning, and the opportunities offered by the resources of the community, were recognised more than a decade before the inception of CfE (National Research Council, 1996, in Cox-Petersen, Marsh, Kisiel, & Melber, 2003). For Scotland, this change could be considered a natural progression of the existing position in which non-formal and informal learning is given parity with formal learning through the Scottish Credit and Qualifications Framework (SCQF) (Leney & Ponton, 2007).

Examining the concepts of informal, non-formal and formal learning is problematic. Definitions are many and varied; usage varies in different contexts (Eraut, 2000) and

remains “contentious, unresolved, and often confusing” (Rennie, 2014, p. 120). In an OECD thematic review of 22 countries across five continents, Werquin (2010) identifies a greater degree of consensus of definition for formal and informal learning, than for non-formal learning. Table 2.1 summarises definitions drawn from the thematic review (Werquin, 2010) and the OECD (2016b).

Formal learning remains the most straightforward to describe and identify, despite an expansion over time of the contexts consistent with formal learning, from recognising only school-based learning for young people (Werquin, 2010). Examples include structured learning within the school system, workplace qualifications, and adult learning which leads to qualifications.

Activities such as watching television or participating in an outdoor walk, from which learning may result, are consistent with the definitions of informal learning (Table 2.1). In informal learning the tendency would be for the learner to recognise retrospectively that learning has taken place; this would not be the defined intention of the activity.

Such is the lack of clarity with respect to the concept of ‘non-formal learning’ that I use the example from Werquin (2010) to illustrate the definition developed for and employed within the OECD study: “a car mechanics course in the workplace (formal learning), in which the students incidentally learn something about themselves (their punctuality, initiative, etc.), or about teamwork or problem solving (non-formal learning). In this case, non-formal learning is incidental to other activities which do have an educational objective.” (p. 23).

Table 2.1 Definitions of formal, informal and non-formal learning

	Environment	Qualifications	Learner role or perspective
Formal learning	Defined by where it takes place, in education and training institutions, or structured settings	Leads to recognised qualifications	Intentional Explicit objectives
Informal learning	Experiential learning through experiences in life and work, never organised	None Recognition of learning experience by the learner likely to be retrospective	Not intentional No set objectives Spontaneous
Non-formal learning	By-product of other activities which may or may not be identified as 'learning'	None	Directly intentional or through intentional participation in a primary activity which leads to non-formal learning as a by-product

Within a report commissioned by the Wellcome Trust on informal science learning, stakeholder interviews and survey information from 149 providers² across the UK (Lloyd, Neilson, King, & Dyball, 2012) are used to attempt to define 'informal learning'. Positioning informal learning as "outside of the formal curriculum...non-compulsory" (Lloyd et al., 2012, p. 2) is problematic in the context of CfE. If informal learning must be outside the curriculum (Schugurensky, 2000) then CfE, a curriculum which recognises learning wherever it happens, requires a different way of thinking. Alternatively, there may need to be an acceptance of informal learning as "a metaphor with a severe problem, namely the lack of systematically and empirically-grounded valid evidence on why, where, when, how and what is learned under 'informal conditions'" (Straka, 2004, p. 2). There is significant divergence of opinion among surveyed providers about: the extent of 'free choice' of participation or activities; whether or not activities could take place on school premises; whether or not the activities could support the formal science curriculum. In attempting to define 'informal learning', Lloyd et al. (2012) merged into

² These providers included " 'suppliers of STEM services'...museums, science and discovery centres, zoos and aquaria, universities, theatre and arts groups and a range of other organisations" (Lloyd et al., 2012, p. 2).

the definition features which others (see, for example, Eshach, 2007; Werquin, 2010) identify as being those of 'non-formal learning'. Lloyd et al. (2012) did not bring any further clarity to the issue, concluding that it is not possible to develop a single definition of 'informal science learning'.

Strict, mutually exclusive definitions of the concepts of informal, non-formal and formal learning such as those employed by the OECD are neither helpful nor reflective of reality. Their usefulness may be more significant in policy decisions than in understanding learning, where their role is limited (Straka, 2009). A more pragmatic approach may be to recognise a continuum of learning, such as that proposed by Werquin (2010) (Figure 2.1) providing a broader spectrum in which to understand learning, with situations fitting in between the categories (Ainsworth & Eaton, 2010). Nevertheless, the terms used and their definitions present contradictions with the aspiration of CfE, and with current practice in Scotland. Werquin (2010) identifies that learning which is not structured by discipline is a feature of informal learning. However, in Scotland schools are increasingly using interdisciplinary learning (IDL) approaches, IDL being one of the four contexts for learning in CfE (ES, n.d.-b). Science centres describe themselves as 'informal learning providers', yet strive to provide deliberate, planned learning opportunities, structured by discipline and connected to the curriculum, situating them closer to formal learning on the continuum (Figure 2.1), albeit without the state regulation or accreditation and quality-assurance mechanisms identified as features of formal learning.

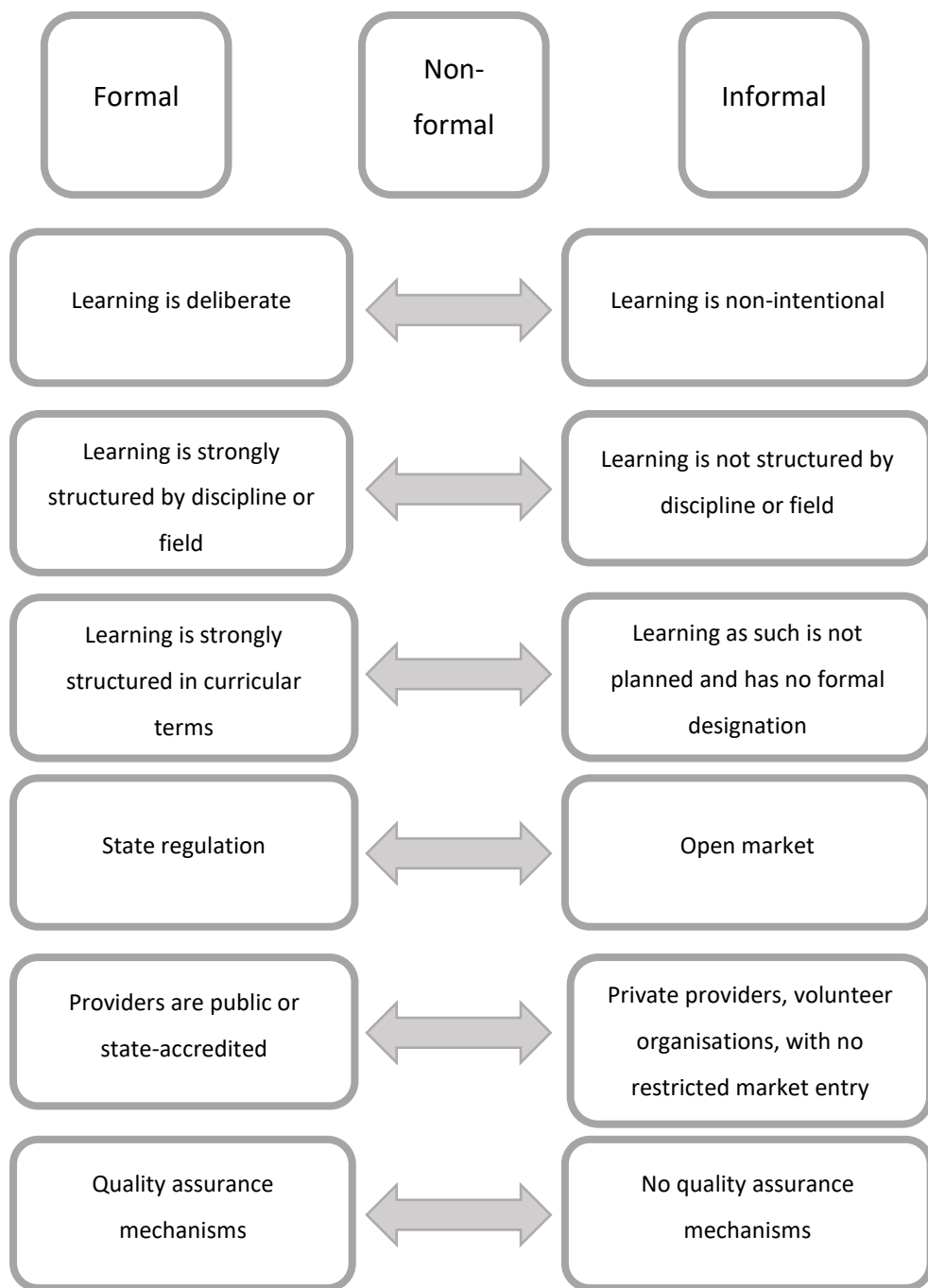


Figure 2.1 The continuum of formal, non-formal and informal learning

(from Werquin, 2010)

The term 'free-choice learning' (Falk, 2001) was proposed as a replacement for 'informal learning' and 'non-formal learning' (Bamberger & Tal, 2007):

Free-choice learning...is self-directed, voluntary, and guided by individual needs and interests...by definition it involves a strong measure of choice - choice over what, why, where, when and how we will learn...for the most part outside of the imposed structure and requirements of schools, universities, or workplaces

(Falk & Dierking, 2002, p. 9).

'Free-choice learning' is underpinned by the idea of 'choice and control', or 'free will' (Salmi, 2003) which is identified as an important or perhaps the key factor influencing learning in the museum context (Falk & Dierking, 2000, in Cox-Petersen et al., 2003; Falk & Storksdieck, 2005; Griffin & Symington, 1997). Falk (2001) emphasises that 'choice and control' need only be perceived, to "qualify as free-choice learning, the learner must perceive that there are reasonable and desirable learning choices (as defined by the learner) available, and that s/he possesses the freedom to select (or not to select) from amongst those choices" (p. 8). Thus, visiting an out-of-school learning setting with a school group may or may not limit the opportunity for learning. Children visiting with a school group do not have a 'real' choice over attending, or the content or topic of the visit, nor control over their schedule or activities whilst at the venue (Lloyd et al., 2012). However, the experience may still be 'free-choice', depending on the participants' perceptions (Falk, 2001).

Efforts of researchers in the field have not led to clarity of definition for informal, non-formal, free-choice and out-of-school learning. These are in any case retrospective labels, unlikely to influence the development of science experiences. In the field of 'informal science learning', studies are exclusively researcher-led; they are not shaped by the participants, whether adults or children (Falk et al., 2012). Attempts to categorise and define are not in themselves particularly meaningful. Whilst representing the development of the language of researchers and developing collective understanding of the field, categories and definitions do not necessarily lead to any greater understanding of science learning beyond school, nor how science experiences can help children learn or enjoy science. In subsequent sections, I explore further the

debate around informal and formal learning, moving beyond definitions to examine how they are compared and contrasted in research studies.

Informal versus formal learning debate

Discussion of informal and formal learning is often framed as informal **versus** formal, presenting the formal setting for learning, the school, in an unfavourable light or with negative connotations (Eraut, 2000; Falk, 2001). Learning in school is represented as a “repressive” experience, in contrast with “supportive” or “usually supportive” non-formal and informal learning (Eshach, 2007, p. 174). Those working in the informal community tend to define “the value of what formal education does by its failures” (Falk et al., 2012, p. 48). I would suggest these are perceived rather than real failures, given the lack of nuanced, evidenced-based understanding of learning and science learning among those working in the informal science learning sector (Falk et al., 2012). This is particularly relevant in the Scottish context, where the far-reaching curriculum reforms associated with CfE have changed significantly what happens in schools, beyond the knowledge, experience and understanding of many working in other sectors. Lortie (1975) identified that “the average student has spent 13,000 hours in direct contact with classroom teachers by the time he [sic] graduates from high school” (p. 61), a calculation which remains broadly accurate for Scotland in 2018. The risk of teachers ‘teaching the way they were taught’ as a result of this “apprenticeship of observation” (Lortie, 1975, p. 62) can be addressed through specific, critical thinking, challenging beliefs and assumptions (Feiman-Nemser, 2001; Mewborn & Tyminski, 2006). However, given the marked distinction and boundaries between those working in science education and those working within informal learning settings (Lewenstein, 2015), what challenge is there to the beliefs of those working in informal settings, formed through such ‘apprenticeship’ which may “mislead [them] into thinking they know more about teaching than they actually do and make it harder for them to form new ideas and new habits of thought and action” (Feiman-Nemser, 2001, p. 1016)?

The previously under-researched area of recognition of non-formal and informal learning examined by the OECD (Werquin, 2010) focusses on the complexities of retrospective accreditation. Yet more complex and challenging is incorporating learning beyond the teacher-led into planned learning and teaching. An analysis of the

connectedness or collaboration between sectors in the science education community, in a study of the contribution of informal providers to the UK science education community undertaken for the Wellcome Trust (Falk et al., 2015; Falk et al., 2012) presents schools in a negative light. They are described as “highly exploitative, dare we suggest parasitic” on the basis that “virtually, all sectors in some way or another catered to the needs of schools but received little service in return” (Falk et al., 2015, p. 163).

The extent of the evidence available to draw this broad, negative conclusion provides an important perspective, given the variability of informal learning experiences, and the paucity of evidence about learning in informal contexts (Bowker, 2010). In January 2012³ there were more than 32000 schools, nurseries and pre-schools in Scotland and England (DfE, 2014; SG, 2012). Within the Wellcome Trust study, these were categorised as one of 18 sectors providing science education experiences. Across all 18 sectors only 51 interviews were conducted in total. Additionally, 196 surveys were completed, primarily by informal education providers, and a further 23 abbreviated surveys by formal providers. For informal and non-formal science learning providers, the motivation to work with and meet the needs of schools may go beyond the altruistic. Schools have access to a ‘captive audience’ of children and can organise trips, visits and activities, incorporating other providers. Building a positive relationship which meets the needs of schools and learners is likely to lead to an income stream for the science-learning providers with opportunities to advertise, market and promote their offerings through schools (Lloyd et al., 2012).

CfE means formal learning in schools in Scotland might well be described as having “the potential to engage students, to teach them, to stimulate their understanding, and most important, to help them assume responsibility for their own future learning” (Gardner, 1991, p. 202). There is clear recognition at a policy and practical level, supported by key reports on the future of the teaching profession published in 2001 and 2011 (Donaldson, 2014; SE, 2000), that “good teachers, good materials, and the right educational atmosphere can make an enormous difference” (Gardner, 1991, p. 248). I have chosen Gardner’s words precisely because these are written not about schools but as a vision of learning beyond school which proposes children’s enrolment in a museum,

³ Figures for England include nursery schools, state-funded primary schools, state-funded secondary schools, special schools, pupil referral units and independent schools

science centre or exploratorium as an addition to, or replacement for, learning in traditional schools (Gardner, 1991). In his well-recognised text, which may be the route through which such ideas have gained traction in mainstream thinking, Gardner (1991) perpetuates a negative view of formal learning failing to match the “genius of the children’s museum” (p. 205). Acknowledging the likely lack of comprehension or, arguably worse, “miscomprehension” associated with “‘one-shot’ visits” (p. 203), it is nevertheless his belief that museums and similar institutions are far more significant than formal schools. Gardner (1991) argues that schools are places in which youngsters read in classrooms or are lectured by teachers about irrelevant and uninteresting subjects.

More than 20 years later, this negative view of formal learning prevails among informal science-learning providers in the UK. A review of 149 informal science-learning providers identified the challenge of inspiring and enthusing children “while being sufficiently relevant to the curriculum to be attractive to teachers” (Lloyd et al., 2012, p. 21), presenting the two as though mutually exclusive. The notion that it not possible for curriculum-linked learning to inspire and enthuse children perhaps speaks more to the lack of vision of the informal science-learning sector of what makes science engaging (Falk et al., 2012) than shortcomings in the formal sector. Despite constraints around formal education, there may be open-ended learning taking place, with the learner at the centre (King & Glackin, 2010). Both schools and out-of-school settings can be places where learning opportunities “are based on the learners’ interests, education includes discovery and/or construction of meaning and students take responsibility for their own activities” (Hein, 1998, p. 7, in Griffin, 2004, p. S65).

Champagne (1975) identifies the significant shortcomings in science centres as a venue for learning: the failure to show what science is really about, “questions are not asked, problems are not set. No relationships sought...there are no theoretical, methodological or conceptual schema taught or even hinted at. Spectacular fun but not science” (p. 37); the inclusion of “sloppy science”; the lack of any ethical dimension to the science; and a dishonest presentation of science as easy, and perfect (p. 39). A number of studies, 20 years on from Champagne’s critique, echoed these criticisms (Rennie & McClafferty, 1996).

A review of 'informal science learning' in the UK commissioned by the Wellcome Trust (Lloyd et al., 2012) identifies a significant gap in the evidence in respect of the long-term impact of informal science learning in the UK (Lloyd et al., 2012). There is a question over whether providers of informal science learning believe evaluation to be part of what they do, and valuable to what they do (Lloyd et al., 2012; Matterson & Holman, 2012). Indeed, there is no evidence of evaluation being carried out in a systematic way (Dillon, 2013). Nor do providers in the UK necessarily value relevant research in social sciences; as a result they do not keep abreast of ideas about the nature of science, and learning (Falk et al., 2012).

Regardless of a lack of evidence of what might be termed 'impact', "people have wondered publicly and privately if the formal science education sector could learn something from the so-called informal sector" (Bevan & Dillon, 2010, p. 168). Some insight can be found in an analysis of UK science education undertaken in 2015 (Falk et al., 2015). When ranking the importance of the various sectors in science education respondents, with the exception of schools, ranked their own sector as much more important to science education than did the average ranking across all respondents, with each sector suffering from "ego-centrism and myopia" (Falk et al., 2015, p. 163).

The informal versus formal approach and the criticism of formal learning is unhelpful. It may lead to an over-statement of the benefits of learning in informal settings by making unfair comparisons with, and assumptions about, learning in formal settings. Conversely, the benefits of informal learning may be overstated precisely because they are not set against a comparison with formal learning; there is much improvement needed in informal learning settings (Eshach, 2007). There is nothing inherent in 'formal learning' or school settings which make them 'bad', nor in 'informal settings' which necessarily make them 'good'. Indeed, there is "no convincing evidence that the fundamental processes of learning differ solely as a function of the physical setting" (Falk, 2001, p. 7).

The value of connected collaboration (Stocklmayer et al., 2010) should be recognised and approaches sought to better connect learning out-of-school with in-school learning (Eshach, 2007). Studies have begun to identify opportunities for bridging between formal learning, and informal and non-formal learning (see Cox-Petersen et al., 2003;

Eshach, 2007; Kisiel, 2003; Lucas, 2000; M. Phillips, Finkelstein, & Wever-Frerichs, 2007) and to explore strategies and approaches to do so (see Bamberger & Tal, 2007; Bamberger & Tal, 2008; Barker, Larson, & Krehbiel, 2014; Bevan & Dillon, 2010; DeWitt & Osborne, 2010; Kisiel, 2014; Stocklmayer et al., 2010). Collaboration and connection requires acknowledgement that contributing to learning is different from increasing awareness, interest in and enthusiasm for science (Lloyd et al., 2012). Definition by outcomes rather than the “delivery methods” of providers is needed, with clear objectives where the science learning is “explicitly intended to contribute to the formal science curriculum...set in terms of enhancing and enriching the curriculum and supporting achievement and progression for students” (Lloyd et al., 2012, p. 50). However, there is no consensus among informal science-learning providers in the UK on the role of informal learning and its connection with formal learning (Lloyd et al., 2012). Whilst almost two-thirds of the 149 respondents in the 2012 review of ‘informal science learning’ consider that their work supports formal learning, highlighting this as an important revenue source and selling point, fewer than half of respondents agree that supporting formal learning should be a main purpose for providers of informal science learning (Lloyd et al., 2012).

Many providers emphasise that they are distinct from formal approaches and learning (Falk et al., 2012; Lloyd et al., 2012; Matterson & Holman, 2012). However, there is little in literature and a lack of reflection among providers on what these distinctive features are; informal science providers criticise formal learning as they attempt to define themselves by what they are not (Falk et al., 2012). Falk et al. (2012) identify a particular irony in informal providers’ criticisms of teachers’ lack of knowledge of out-of-school science experiences given the lack of training and professional development opportunities in the informal sector. The single most important factor in determining children’s learning and the success of education is the quality of the teachers and teacher education system (Qvortrup, 2008). In a 2013 Wellcome Trust survey which included views of science education, the most commonly mentioned factor which encourages or discourages young people when learning science is the quality of the teacher (Wellcome Trust, 2013). There must be recognition of the complex, challenging nature of teaching (Donaldson, 2014), and the rapid nature of change within the formal-learning system in Scotland which has moved the teacher from “deliverer of information to...curriculum developer” (Wallace & Priestley, 2017, p. 327). Attention

must be paid to supporting the learning of those who mediate and facilitate science learning in informal settings. Without this recognition and attention, the effort and funding invested in developing informal providers as learning resources may be under-utilised or wasted (Schauble et al., 2002).

The setting for informal learning provides a distinction from formal learning. Early studies in the field of informal learning identify the potential for ‘off-task’ behaviour of children in school groups visiting museums and science centres as a result of the novelty of setting (Salmi, 2003). The positive attitudes of learners associated with field trips were identified as having as much to do with avoiding school as the opportunity for learning (Salmi, 2003). Subsequent studies endeavour to identify strategies to use the novelty of the setting to enhance learning (Lucas, 2000). Whatever is at its root, there is both a challenge and an opportunity for informal providers to harness any positive attitude that comes with the change of setting to stimulate learning. Despite this, providers often miss opportunities for learning that take advantage of the distinct setting (Cox-Petersen et al., 2003), imposing classroom structures and teaching strategies more appropriate to a ‘formal’ setting (Griffin, 1994, and Olson, 1999, in Griffin, 2004, p. S60; Griffin & Symington, 1997). Using didactic, adult-led models of interaction, and delivering content rather than facilitating learning (Cox-Petersen et al., 2003), providers do not recognise the “absurdity” of suggesting that “seating children in a museum auditorium and requiring them to hear a lecture is somehow different from seating children in a school auditorium to hear a lecture.” (Falk, 2001, p. 7).

Thinking that learning is easier when it is fun, and that fun is a key motivator for children in learning science is widespread. Scottish Government (SG) identifies this as a driver in science experiences (2017b) and many science experiences promote themselves on the basis of fun (see, for example, GSC, 2017; DSC, 2017; University of Edinburgh, 2017; University of Oxford Department of Education, 2014). What is meant by fun and its conceptualisation is complex (McManus & Furnham, 2010). There is little in research which explores the notion of fun in relation to learning and education; it is ill-defined and widely misunderstood (Gray, 2010). Fun is often equated, or confused, with humour, engagement, pleasure and excitement, with little to illuminate fun in itself and how it promotes or relates to learning (see, for example, Growth Engineering, 2017; University of Edinburgh, 2017) and with little conceptual

clarity (McManus & Furnham, 2010). Arguably, fun is not the same as play or games; fun is not an activity, nor is it a purpose, but rather it is part of a process or a state (Gray, 2010).

Much of the research available about fun and learning is concerned with software design development, because of the significant need in this area to understand how to engage users within their leisure time (Draper, 1999). In his exploration of fun in software development, Draper (1999) explores the work of Langer (1997) and in particular that an emphasis on fun “sends the message that learning is inherently unpleasant, when without that students might well be brought to experience it as intrinsically enjoyable” (Draper, 1999, p. 121). An emphasis on fun within science experiences may be sending a negative message about science learning generally. An emphasis on enjoyment through challenge, or “unusual investments of attention” (Csikszentmihalyi, 2002, p. 46), rather than through fun, might be more beneficial regardless of the setting or the provider.

There exists, then, a contradiction. Out-of-school science learning providers seek to present themselves as distinct from, yet valuable to, formal learning. Promoting and emphasising their connection to the formal curriculum, they emulate what they perceive as typical approaches from formal environments without having an understanding of such environments, nor of contemporary thinking about science learning, engagement or motivation (Falk et al., 2012). In Scotland, this contrasts with demands faced by the teaching workforce for increasing professionalisation and levels of qualification (Donaldson, 2014), expectations of using research and evidence about learning to inform practice (GTCS, 2012b), and the shift from teacher as ‘curriculum transmitter’ to ‘curriculum maker’ (Wallace & Priestley, 2017). Tensions exist between informality and playing a role in formal learning. A loss of ‘distinction’ may be necessary: the greater the scaffolding to support learning in an informal environment, the less the “informal behaviours” (Yoon, Elinich, Wang, Van Schooneveld, & Anderson, 2013, pp. 873-874). There is evidence of this approach in natural history museums, and recent research suggests that there may be benefits to learning as a result (Mujtaba, Lawrence, Oliver, & Reiss, 2018).

Learning science beyond school

The broad view of the curriculum in Scotland does not benefit from definitions and categories. More useful is an understanding of connecting learning in and out of school, rather than leaving children to construct this individually and retrospectively. Participating in school trips to informal environments, children and young people themselves make connections between the visit and prior learning in school, and subsequently with new learning in school, despite connections not being made by their teachers or museum staff (Bamberger & Tal, 2008).

The role of learning in informal settings is contested (Falk & Dierking, 2010). In studies that “seek to justify the introduction of systems for recognising non-formal and informal learning outcomes” there are concerns over data quality, study validity, and accuracy of claims made (Werquin, 2010, p. 21), with research over-reliant on surveys, lacking a research question and failing to include the research instrument (Falk et al., 2012).

The challenge of measuring the influence of in and out-of-school science learning cannot be underestimated (Amos & Reiss, 2012; Falk & Dierking, 2010). The majority of informal science institutions do not have the resource available to conduct in-depth, long-term studies, citing budgetary, time and staff constraints as well as a lack of relevant expertise (King, Steiner, Hobson, Robinson, & Clipson, 2015). In research related to school visits to informal settings⁴, immediate, short-term cognitive benefits are more commonly examined than longer-term impact (Bamberger & Tal, 2008). In the UK, sector evaluation focuses on visitors’ short-term views of science, alongside delivery processes and audience satisfaction, with medium- to long-term impact rarely assessed (Lloyd et al., 2012). In the USA, where the tradition of informal science learning is longer established than in the UK, a 2007 survey of informal institutions revealed that while 93% undertake evaluation, only 25% of providers use methods which investigate whether there are changes in the behaviour and attitudes of teachers, children, or in achievement of children as a result of engagement (M. Phillips et al., 2007).

⁴ In this study, situated in the National Museum of Science, Technology and Space in Israel, the terms science centre, science museum and museum are used interchangeably to refer to the site of the research. ‘Museum’ is also used in its broadest sense throughout the study, aligning with usage by Falk & Dierking (2000).

What is known about science learning other than that which happens in schools? Children's early interest and initial learning in science can take place as part of free-choice learning experiences outside school (Falk & Dierking, 2010; Mack et al., 2012). Children may use information gained from experiences outside school to build and clarify understanding as they learn science more 'formally' (Bell, Bricker, Lee, Reeve and Zimmerman, 2006, cited in Mack et al., 2012) and may build their knowledge and understanding of scientific concepts through a wide range of experiences (Mujtaba et al., 2018). In the cultural-historical perspective, 'Vygotskian' play, role-play or imaginative, collaborative play, has a crucial role in early science learning (Murphy, 2012). Cox-Petersen et al. (2003) cite Falk and Dierking's research (1997) as evidence that school trips to informal environments promote recall of science content in the long-term. The original study of 128 children, young people and adults, was based on the premise that memories, prompted by a series of questions, represent "evidence of learning" (Falk & Dierking, 1997, Conclusion para. 1). However, the study does not include a balance of perspectives, and presents the outcomes relating to the informal environments in an uncritically favourable light. Seeking to determine 'impact' of school field trips, the criteria applied as evidence of learning sets the bar low, with a very limited view of the experience of learning based on availability of information for possible future application (Ausebel, Novak & Henesian, 1978, in Falk & Dierking, 1997, Conclusion, para. 5). The study identifies that nearly all interviewees can recall one fact about a school field-trip in their early years of school, with most able to recall three or more. Content or subject matter of the place visited is the focus of 75% of recollections; in "several cases" the "information learned on a field trip was generalized (sic) to other experiences and situations" (Falk & Dierking, 1997, Conclusion para. 4). "How many other one-day school experiences would measure up as well?" ask Falk and Dierking (1997, Conclusion para. 7). Single-day school experiences are not given the opportunity to 'measure up'. Within the study, participants are not asked to similarly identify one day of school which was particularly memorable and answer the same prompt questions to explore this further. Nor is it established whether the recollected content is indeed related to the field trip in question.

There is evidence that learning involving residential field work outside the classroom has a greater effect than the same experience within the classroom, even when the novelty of the setting is taken into account (King & Glackin, 2010; Nundy, 1999).

Fieldwork has the potential to support the development of socialisation in children from socially-deprived backgrounds and to provide opportunity to 'do science' and participate in "science inquiry in authentic settings" (Amos & Reiss, 2012, p. 506). Like learning in the classroom, learning outside the classroom takes place only if carefully and thoughtfully planned and constructed (Nundy, 1999). More difficult to achieve on a single visit, the absence of planning to create the conditions for learning perhaps explains the lack of learning as a result of a "'one-shot' visit" to an informal setting (Gardner, 1991, p. 203).

Bamberger and Tal (2007), in a study of around 750 children visiting museums⁵ with their schools, found that museum education staff lack knowledge of the research around learning in free-choice environments. Undoubtedly, there are challenges. Existing research evidence is generally not from the UK (Matterson & Holman, 2012) and is published across a range of disciplines, making it difficult to locate (Falk et al., 2012) and for those working in the sector to identify and integrate into practice including for reasons of cost and readability (King & DeWitt, n.d.). This lack of knowledge leads to implementation of one of two models: completely undirected exploration, or authoritative transmission of information ('no choice' scenarios) (Bamberger & Tal, 2007). Within the no-choice scenario, in only 15% of the 29 observed visits did museum staff attempt to prompt linking to the curriculum (Bamberger & Tal, 2007). Questioning to explore students' prior knowledge, a key factor influencing learning in the museum environment (Falk, 2005), was closed, and used simply to "proceed with the lecture" (Bamberger & Tal, 2007, p. 85). In this scenario, the extent to which learners are on- or off-task relates to the individual presenter's personal teaching skills and personality (Bamberger & Tal, 2007); an individual influence which is very difficult to predict or plan when trying to connect with or support formal learning.

The benefits of participation in science experiences may extend beyond learning for the purpose of connection to formal education, attainment and qualifications. Wider benefits of residential science-learning experiences include raised self-esteem among young people, improved behaviour and better relationships between peers, and

⁵ The term 'museum' is used by Bamberger and Tal as it is used by Falk and Dierking (2000, p. xi, in Bamberger & Tal, 2007, p. 79). In this study it includes a science museum; natural history centre and a zoological centre (Bamberger & Tal, 2007, p. 79).

between teachers and young people (King & Glackin, 2010). In a majority of OECD countries, there are broader benefits in terms of attainment associated with attendance at schools offering “extracurricular STEM enrichment activities, such as excursions, field trips, science competitions and science fairs” (PISA, 2006, cited in Frontier Economics, 2009, p. 19). Children participating in such STEM enrichment activities have greater belief in their ability in science, and have more positive attitudes towards science (Falk et al., 2012). Significantly, for children in the UK, the positive effects exist only for those in a higher socio-economic group (Falk et al., 2012).

Encouraging children to consider careers in science and STEM is an objective of many informal science-learning providers (Lloyd et al., 2012). This does not translate into practice with “little attention [is] being paid directly to arguably the important goal of preparing individuals for science-related careers” (Falk et al., 2015, p. 162). Nevertheless, children indicate that, in common with the “perceived extrinsic value of science qualifications” (Falk et al., 2012, p. 15), informal science experiences may initiate interest in science even where it “cannot be readily measured” (Falk et al., 2012, p. 15). Out-of-school settings can provide opportunities for children to be exposed to professional scientists and to increase their understanding of career paths available and necessary qualifications (P. Bell et al., 2009; King & Glackin, 2010). However, such settings are not unique in their ability to do so as King and Glackin (2010) suggest.

In a Finnish study of reasons for career choices, almost 80% of 1019 first- and second-year undergraduate students had visited the Finnish Science Centre Heureka (n.d.) prior to commencing their studies at university, with the highest attendance among students of natural science, social science and technology, and the lowest among students in the veterinary department (Salmi, 2003). Those indicating that hobbies and informal learning influenced their career choices identify a science centre visit as an essential element in their choice (Salmi, 2003). In contrast, a survey of 900 children aged 11-14 participating in an interactive science event in the UK offered by active university researchers, identified that participation did not educate or enthuse the children about careers in science (Illingworth, Lewis, & Percival, 2015, p. 10). The findings from Salmi (2003) and the research conducted by Illingworth et al. (2015) appear contradictory. However, the younger group in Illingworth et al. (2015) responding to the survey may have been reflecting on a single event compared with undergraduate students

reflecting on the cumulative effect of out-of-school learning over a longer period of time. Is there a difference between the retrospective recollections of the university-aged group and the views of children captured at the time? The survey with 900 children suggests that such engagement may not be influential in career choices, at a time when choices are made which will impact career paths. Salmi's (2003) study requires careful interpretation. The visit to the science centre may have influenced career choices. However, those who reported this may have been pre-disposed to choosing a career in natural science or technology. They may also have been more likely to have been interested in these subject areas as hobbies, thus enjoying the science centre visit and crediting it with impact on their decision making. Veterinary studies are arguably science related and yet the lowest science centre attendance is recorded among this group. There remains an unanswered question: if the science centre did not exist, would the career choices be different?

Recommendations for informal science-learning providers arising from research tend to be in agreement, calling for more detailed planning, better connection with formal learning, for students' backgrounds to be taken into account, and for activities to be supportive of the curriculum and the teacher (Illingworth et al., 2015; Rennie & McClafferty, 1996). As an example of these recommendations in practice, Salmi (2003) identifies a positive effect on intrinsic motivation among children within particular age ranges visiting a science centre monthly for one school year. This impact is dependent on "well planned educational program(s)...linking schools to the informal learning settings of science centres" (Salmi, 2003, p. 469). In a study of 2597 informal science institutions (ISIs) in the USA, Phillips et al (2007) rejected the idea of one-day field trips playing any role in supporting school science education. Phillips et al (2007) included in this large-scale study only those field trips which were structured, and had an element of educational support with activities either before or in follow-up to the visit. Amos and Reiss (2012) emphasise the critical need for pre- and post-fieldwork input in supporting children's progress.

Maximising learning out-of-school requires advance planning, including preparing students to overcome the 'novelty' of the setting, planned questioning to encourage deep learning and post-experience follow up (King & Glackin, 2010). Recall of the experience and reflection on it requires mediation of some form; prompts such as

photographs and films of the experience used as ‘hooks’ for future learning can increase the learning from an experience in an informal setting (DeWitt & Osborne, 2010; King & Glackin, 2010). The class teacher has a role to play in maximising the learning from the experience, particularly where there are opportunities for shared teaching (King & Glackin, 2010). However, the extent to which interactions between formal and informal providers include time for the kind of quality exchanges required to effectively mediate learning or to plan shared teaching is questionable. Finding no difference in the learning of student undertaking laboratory experiments in an out-of-school setting compared with those doing the same work in school, Itzek-Greulich et al. (2015) identify that there is seldom opportunity for teachers to be actively involved in facilitating learning in the out-of-school laboratory setting.

Perry (2012) proposes a “what makes learning fun?” framework for museum experiences incorporating the principles of communication, curiosity, confidence, challenge, control and play. This framework takes as a starting point the notion that fun is not in itself sufficient; there must be challenge and enjoyment in *learning*. This view is supported by Archer et al. (2013b) who suggest that to increase uptake of STEM subjects and careers, it is necessary to move beyond the interesting and fun into building ‘science capital’. The concept of ‘science capital’ is visualised by DeWitt, Archer, and Mau (2016) as a holdall into which is gathered ‘who (science-related) you know’, ‘what science you know’, ‘how you think (about science) and ‘what you do (related to science)’. Fun might be considered an influencing factor in the latter three of these elements. However, given that school and home are of greater importance than spaces such as science centres in developing science capital (DeWitt et al., 2016), the idea of ‘making science fun’ through science experiences, suggesting that “learning science is in itself inherently unpleasant” (Draper, 1999, p. 121) may ultimately be more harmful than beneficial to building science capital.

Arguably, a deeper understanding of fun rather than a superficial idea of aiming to be unlike school is likely to be more beneficial. Draper (1999) argues that fun, considered as an intrinsic motivation, is about the relationship between the “activity and the individual’s goals at that moment” (p. 118) including how much challenge the individual wishes to face at the time of the activity. This aligns with Csikszentmihalyi’s flow theory in which “one must be able to concentrate and interact with the

opportunities at a level commensurate with one's skills" (Csikszentmihalyi, 2002, p. 119). Jones (1998) summarises the eight major components of flow theory described by Csikszentmihalyi (2002): "task that we can complete; ability to concentrate on task; task has clear goals; task provides immediate feedback; deep but effortless involvement (losing awareness of worry and frustration of everyday activity); exercising a sense of control over our actions; concern for self disappears during flow, but sense of self is stronger after flow activity; sense of duration of time is altered" (Jones, 1998, p. 206). Fun must be recognised as more than entertainment, and its role in learning better understood rather than simply assuming that fun is likely to improve engagement with sciences.

There is a need for those working in informal science learning to "communicate their content knowledge in a pedagogically adequate way" (Price & Hein, 1991, in Itzek-Greulich et al., 2015, p. 49), using evidence in their practice, and developing a better understanding of how science learning happens, and of what makes science engaging and interesting (Falk et al., 2012). Whilst experiences in settings other than school can be beneficial for science education, this benefit does not happen automatically (Itzek-Greulich et al., 2015).

Learning science beyond the teacher-led in Scotland

The narrative surround science learning outside school and science experiences in Scotland is predominantly positive and uncritical: science experiences through external providers enrich and enhance science learning and are to be encouraged. This is not unique to Scotland. Despite a lack of evidence about what is learned, and how it is learned, "'informal' and 'non-formal' learning are given high esteem...in educational policy" (Straka, 2004, pp. 13-14).

'Informal' science learning provision

Significant Scottish Government funding is directed to science centres and festivals in Scotland (see, for example, SG, 2013a; 2014a, 2015a, 2015b, 2015d, 2017c). However, the picture of provision in Scotland is complex and the landscape both crowded and

confusing (SG, 2017c; Scottish Science Advisory Committee, 2003; SSAC, 2011)⁶. Numerous and varied organisations and providers work on a range of activities and engagement on an individual school, education authority or national basis (SSAC, 2011). There is a lack of information and clarity regarding the ways in which schools engage with industry, professional institutions, learned societies and academia to make use of opportunities to enhance and enrich learning in sciences and STEM (SSAC, 2011). Whilst the provision of STEM activities in Scotland is not quantified, a review commissioned by the Department for Education and Skills identified that there were more than 470 STEM initiatives across the UK, run by government and external agencies (Great Britain: Parliamentary Office of Science and Technology, 2011). There exists no guidance relating to quality or standards of such engagement, or what constitutes ‘good practice’ (SSAC, 2011) with respect to activities supporting learning in science. Nor is there any guidance available on the evaluation or impact of such activities in respect of progression of learning.

This is not a new issue; the need for a co-ordinated approach stimulated the initiation of the Institute for Science Education in Scotland (Scottish Science Advisory Committee, 2003), a project which did not progress. In 2012, SSAC and other partners recommended that co-ordinator posts be set up to act as “central co-ordinators for science-related schools [*sic*] activities...and schools [*sic*] science engagement” (SEEAG, 2012, p. 33). The first and only such co-ordinator appointed on a 24-month secondment between 2013 and 2015, described achievement of a much-reduced set of outcomes against a much narrower remit (Bryce, 2015) than envisaged.

In 2012 SEEAG, drawing on the work and recommendations of the SSAC (2011) report and echoing their findings regarding the complexity of the landscape of activities to support STEM, reported to Scottish Government on supporting STEM education and culture in Scotland (SEEAG, 2012). In exploring how to increase children’s engagement with ‘real life’ STEM, SEEAG recommended that industry input and engagement be developed in partnership with those who can give guidance on appropriate pedagogy, and how best to align such engagement with CfE and the needs of learners. Despite this significant gap in the provision, SEEAG positioned itself with a positive stance

⁶ SSAC is the Scottish Science Advisory Council. The title was amended from ‘Scottish Science Advisory Committee’ following changes to its role and reporting arrangements in 2008.

towards the “strong ‘science engagement’ sector” (SEEAG, 2012, p. 68), science centres and festivals. Financial and other support provided to science centres and festivals by Scottish Government (SG, 2015a) was described as “essential and **effective**...to fulfil their **valuable roles** [emphases added]” (SEEAG, 2012, p. 117). In contrast, a 2009 UK Government report assessing the value or money of science centres compared with other STEM-related activities was unable to do so because of a lack of evidence about the long-term impact of science centres (Frontier Economics, 2009). In the absence of such evidence, the report authors were unable to be conclusive on whether there was a case to support science centres through Government funding (Frontier Economics, 2009).

The outreach element of the work of science centres and festivals is emphasised by SEEAG (2012) as being of equal importance to work undertaken within the centres and at festival venues. A recommendation is made for direct funding from Scottish Government to ensure that ‘deprived’ and remote communities have opportunities for public science engagement within half an hour’s travel time (SEEAG, 2012). This recommendation differs significantly from the conclusions of a Scottish Executive commissioned review in 2007:

it was universally accepted that there is a need for better co-ordination of outreach activity across the whole of the STEM sector to ensure that those activities that are delivered are reliable, appropriate and worthwhile...there is some outreach where delivery is not of a standard which is acceptable, and this needs to be looked at to ensure that there is better quality assurance in place...there are **significant negative impacts of a poor outreach experience** [emphasis added] both for pupils and for the value placed on science communication.

(Halcrow Group Limited, 2007, p. 20)

SEEAG (2012) also recommended that every school should visit a science centre or science festival on an annual basis, identifying Scotland’s provision of science centres and festivals as “by far the best within the British Isles” (SEEAG, 2012, p. 94). These statements and recommendations are not supported by data or evidence included in the publicly-available report and its references. The SEEAG Catalogue of Evidence (SG,

n.d.-b) includes written submissions from two of Scotland's four science centres, focusing primarily on activities and the number of participants. This approach of providing information rather than evidence is typical in studies associated with examining the impact of 'informal learning' in science in the UK (Frontier Economics, 2009). In the concluding paragraph of their submission to SEEAG, DSC argues that engagement "can have significant life-enhancing impact for participants, and this ... must not be undermined by quantitative measurement" (DSC, 2011, p. 2). This resistance to systematic evaluation is not untypical of a sector that does not view evaluation to be part of, or valuable to, what they do (Lloyd et al., 2012; Matterson & Holman, 2012).

The positive stance taken by SEEAG in relation to science experiences contrasts with that of a DfES report published in 2006:

...at the current time we have far too many schemes, each of which has its own overheads. The original STEM Mapping Review in 2004 revealed over 470 STEM initiatives run by DfES, DTI and external agencies and subsequently, the STEM cross cutting programme examined around 200 of these. They are not, therefore, in total either efficient or effective and do not give a complete coverage of all schools.

(Great Britain: DfES, 2006, p. 3)

In 2011, The Parliamentary Office of Science and Technology summarised the position with respect to research and understanding of science and STEM experiences:

Measuring the impact of informal STEM education is not straightforward ...impact is difficult to attribute to specific activities. Several reports demonstrate a correlation between childhood informal STEM education experiences and STEM interests later on in adulthood. However, proving direct cause and effect for particular experiences would require long-term follow-up studies, making such research resource intensive and difficult to achieve for every initiative (p. 2).

The Scottish Government remains the only UK Government providing financial support to science centres (Somerville MSP, 2017). Of the external providers and organisations which aim to support science learning in CfE, the science centres in Scotland are the most evaluated by Scottish Government. Therefore, in this section I examine evaluation and review carried out since the four Scottish science centres formed the Scottish Science Centres Network (SSCN) in 2005, coinciding with the time period in which CfE has been developed and implemented. I discuss the evaluation and reviews from the perspective of contribution to ‘formal learning’.

Scotland’s science centres: history and funding

The history of Scotland’s science centres is such that there exists a tension between their role in education and their operation as commercial visitor attractions including catering and gift shops. At the same time as the National Debate on Education (SE, 2002) was taking place, the membership of a new Scottish Science Advisory Committee, formed under the auspices of the Royal Society of Edinburgh, was announced (SSAC, n.d.). The first of the Committee’s reports published in November 2003 recommended that the “Scottish Executive should find a means to provide financial support to ensure the sustainability of the Scottish Science Centres” (Scottish Science Advisory Committee, 2003, p. 7). Typically, the science centres operate charitable trusts, alongside one or more limited companies (DSC, 2018a; Dynamic Earth, 2018a; GSC, 2018a). Of the five centres opened in Scotland in 2000 with capital funding from the Millennium Commission, four remain. By 2003, one of the centres, the Big Idea at Irvine, had gone into voluntary liquidation with significant debts, despite additional public funding awarded by the Scottish Executive to support the centre (British Broadcasting Corporation, 2003; Watson, 2016). Whilst the Chair of the Centre had been determined to prove that a science centre could be operated without public subsidy, “I failed. There is not a single science centre which operates without it. If it is important to Scotland to have such science centres, we will have to find a way of getting regular public subsidy, because we are all living on a knife edge.” (John Moorhouse in The Scotsman, 2003).

In these first few years of the 21st century, there were job cuts at Scotland’s other science centres, whilst falling visitor numbers at the established Royal Observatory in

Edinburgh (RoE) “forced it to concentrate on science education rather than tourism” citing a “widespread over-optimistic and over-simplistic view that these [centres] can be self-financing” (Dan Hillier, RoE, in *The Scotsman*, 2003). The RoE subsequently secured £300k of funding from the Scottish Executive to offer continuing professional development for teachers including trips to the centre for children (RoE, n.d.). In 2008, the operations of one of the Scottish science centres had to be taken over by another, with reductions of overheads of £200k and redundancies necessary to sustain operations (Heal, 2008).

Scotland is not alone in facing these challenges. An inquiry by the Parliamentary Select Committee on Science and Technology in 2007 identified that the revenue projections of the science centres opened with capital injection and stabilisation funding from The Millennium Commission, were unrealistic; indeed they were categorised as ‘fantasy’ (Great Britain: House of Commons Select Committee on Science and Technology, 2007). The challenge and cost of maintaining ambitious buildings was recognised. In designing the science centres, all were “encouraged to think big...they are expensive buildings to run” resulting in a mismatch between the small businesses operating within buildings more appropriate to medium to large businesses (Great Britain: Parliament: House of Commons Science and Technology Committee, 2007, Ev 5). In light of this, the on-going financial challenges of Scotland’s science centres are not unexpected. In 2013, operation of the IMAX cinema at one of Scotland’s science centres was contracted to a commercial cinema operator (IMAX Corporation, 2013) with staff also transferred (GSC Charitable Trust, 2014). The operator is obliged to continue to show educational films, and is paid to do so by the science centre (GSC Charitable Trust, 2014).

The House of Commons Select Committee made a recommendation not to award long-term Government funding until there existed rigorous evidence of the benefits of science centres, either in encouraging children in STEM or influencing the public debate around science (Great Britain: House of Commons Select Committee on Science and Technology, 2007). Science centres typically achieve only around 70% of the income they need through commercial activities (Great Britain: Parliament: House of Commons Science and Technology Committee, 2007) including visitors, catering and expenditure in gift shops. Thus, it is almost inevitable, in the absence of funding from private trusts, business and industry, that a proportion of funds for supporting learning must be used

instead to meet overhead costs, including the costs of running and maintaining expensive, ambitious buildings.

In the financial year 2013/14, one of the Scottish science centres received funding of £904k from Scottish Government. In addition, two local authorities funded one visit per year for every child in their primary and assisted-needs schools, a total of 15715 children in 2013/14. An additional 13990 children visited using further funding for transport subsidy provided by the Scottish Government. In that same year, costs for refurbishing elements of the building were budgeted at £1.77 million, and ultimately cost £1.849 million, including funding of £376k from one of the local authorities already funding a visit per year for every child in a primary or assisted-needs school (GSC Charitable Trust, 2014, 2015). There were redundancies and removal of posts within the science learning team despite an overall increase in staff numbers (GSC Charitable Trust, 2014, 2015). The year was considered particularly strong for visitor numbers due to the opening of a major new exhibition, borne out by a slight decrease the following year (GSC Charitable Trust, 2014; GSC Charitable Trust, 2015). Income from visitors in 2013/14 was just over £1.3 million. 'Voluntary' income was just under £1.3 million including a Scottish Government grant of over £900k and the remainder from donations and 'gift aid' (GSC Charitable Trust, 2014). Potential reduction of the funding from Scottish Government was identified as a key risk, although for 2014/15 the science centre was awarded more than £922k, an increase compared with the 2013/14 award. The tensions are perhaps best illustrated by looking at staffing numbers for this one Scottish science centre, which in 2014/15 employed 34 people in customer experience, 38 in retail, corporate hospitality and catering, 32 in facilities and exhibits, and 24 in science.

For Scottish science centres aspiring to support CfE, these tensions may lead to a lack of time and funding to explore and understand CfE, learning and pedagogy. There is, then, a risk of preparation of scripted workshops and activities to be delivered, which neither meet the needs of learners nor progress their learning.

Scotland's science centres: review and evaluation

In 2007, HMIE published a *Review of the contribution made by the Scottish science centres to formal and informal learning*. The review process comprised a week-long visit in each of the four centres, based in Aberdeen, Dundee, Edinburgh and Glasgow, and included “discussion with visitors, including members of the public and school groups” (HMIE, 2007, p. 4). Comment on learning and teaching at one of the four centres was overwhelmingly positive, with aspects of provision for secondary-aged pupils identified as high-quality. Two of the four centres were identified as having well-qualified education staff. Weaknesses included factual errors in workshops and shows, limited pre- and post- visit resources for teachers and pupils to prepare for and follow up learning during the visit, failure to match presentations to pupils’ existing knowledge and understanding, use of closed questioning, lack of opportunity for problem-solving and investigation, lack of inclusion of aspects of CfE, and limited consultation with teachers and learners (HMIE, 2007). In more than one of the centres, there was a lack of focus on the learning of young people, and evaluation was not systematic or rigorous (HMIE, 2007). The weaknesses reported align with those identified in the literature on learning in science centres and museums (Bamberger & Tal, 2007; Cox-Petersen et al., 2003; Eshach, 2007; Griffin, 2004).

Much of the HMIE report is a summary of *what the science centres do*, as opposed to exploring in any depth how the science centres *contribute to or impact on* learning. Nevertheless, the then Chief Scientific Adviser for Scotland and Chair of SEEAG cited the review as “a valuable assessment of the **quality of the education** [emphasis added] service across the Scottish Science Centres Network”, highlighting the potential of the centres to “play a central role in complementing and enhancing the science curriculum, particularly the emerging *Curriculum for Excellence*” (HMIE, 2007, p. V).

A separate review in 2007 intended to inform future policy with respect to the SSCN identified that “it was underlined by the then Scottish Executive Education Department that currently the science centres are considered to be only one of a number of resources that could be used to support the outcomes arising from A Curriculum for Excellence” (Halcrow Group Limited, 2007, p. 12). This review was less conclusive about the SSCN’s role in formal learning:

The onus remains on the SSCN to demonstrate clear linkages between the school visits to the science centre and the school curriculum, and how this learning is developed before and after the visit has taken place. There is currently no systematic or consistent approach in terms of how a visit to a science centre is integrated within the school science curriculum. The tendency for visits to be concentrated at the end of term underlines that visits to the science centres are in many cases considered as more of an end of term treat rather than an important part of science learning. This means that the science centres are competing as one of many options for a potential school trip rather than being considered to be an integral part of the science curriculum.

(Halcrow Group Limited, 2007, p. 19)

Three reports reviewing science centres in Scotland and the UK were published in 2007. These reports highlight the differing views about the role of science centres and future of the SSCN. From those within the education system in Scotland, HMIE and the Chief Scientific Adviser, it seems that there is motivation to place the SSCN firmly within the developing CfE, despite a lack of research evidence regarding the role of science centres in learning or evidence that the SSCN was in a position to play such a role. One driver for this may have been the need to have a route through which to positively promote CfE, in the face of an increasing loss of political consensus which led to a delay in implementation and the threat of industrial action by teachers (Murtagh, 2010). Research undertaken in one education authority in 2010/11 indicated a sense that some schools were resistant or slow to implement CfE, with only 30% of teachers and head teachers agreeing that national guidance was helpful in planning the new curriculum (Priestley & Minty, 2012).

Another driver may have been to secure funding and through this the future of the SSCN, with the recognition that science centres are not able to generate more than around 70% of their running costs and overheads through their commercial activities including visitors (Great Britain: House of Commons Select Committee on Science and Technology, 2007). Linking to 'formal education' is recognised by providers such as science centres as an important revenue stream and selling point (Lloyd et al., 2012).

In Scotland, responsibility for funding of science centres was transferred from the Scottish Executive to the Office of the Chief Scientific Adviser for Scotland in 2006 (HMIE, 2009). HMIE recommended the Scottish Executive should provide longer term funding for the centres, and additionally provide funding to cover the cost of school visits and transport to the science centres to financially strengthen the centres (HMIE, 2007). Subsequently, a package of £2.56 million per year for a three-year period was awarded, with an additional £250k for provision by the SSCN of continuing professional development for primary teachers (HMIE, 2009). This award was made despite an absence of any evidence that the SSCN was in a position to offer professional development for qualified teachers. The funding package included an element of transport subsidy, one of six options for ‘intervention’ explored by the Halcrow Group review (Halcrow Group Limited, 2007). Free transport for schools, whilst costing significantly more than the other options considered, was identified in the analysis as the route through which there would be the greatest increase in visits and most significant increase in admissions revenue for the science centres (Halcrow Group Limited, 2007).

A 2009 follow-up review of the SSCN by HMIE noted progress against the action points identified in 2007 for each of the centres, although these were not detailed, and the successful use of Scottish Government funding to improve educational provision, concluding that “science centres have an important role to play in supporting the needs of children, young people and their teachers” (HMIE, 2009, p. 14). Research into the SSCN, commissioned by Scottish Government and published in 2011, explored the visitor experience and satisfaction with a focus on immediate reactions of visitors (Morris Hargreaves McIntyre, 2011). Over 70% of the sample of 6054 visitors over a two-year period were in family groups, defined as groups including accompanied children aged under 16 (Morris Hargreaves McIntyre, 2011). From 2008/9 to 2009/10 the number of visits by ‘learning families’, defined as families, new or repeat, visiting with children for an intellectually-motivated visit decreased by 15% (Morris Hargreaves McIntyre, 2011). The interviewer-led survey was conducted only with adult visitors. School groups were specifically **excluded** from the research which concluded that “Scottish Science Centres are family-friendly visitor attractions delivering significant learning outcomes around science” (Morris Hargreaves McIntyre, 2011, p. 1). This exclusion of children in school groups is not untypical of research into out-of-school

learning; the few studies including children do so for family groupings as opposed to visits with school groups (Griffin, 2004, p. S61). However, in out-of-school learning settings “school students are treated differently from children in family groups” (Hein, 1998, cited in Griffin, 2004, p. S67). It cannot be assumed that understanding developed about children’s experiences as family-group visitors provides insight into their experiences with a school group.

Table 2.2 lists the ‘learning outcomes’ used in the Morris Hargreaves McIntyre (2011) report, and the percentages of those surveyed who agreed or strongly agreed with the statements. Between 2008/9 and 2009/10 there was a decrease in agreement or strong agreement with each of the statements. However, without further data it is not possible to ascertain statistical significance, discern trends or offer possible reasons for this.

Table 2.2 Percentage of participants who agreed or strongly agreed with learning outcome statements in Final Visitor Research Report 2008-10: Scottish Science Centre Evaluation

Statement	% who agreed or strongly agreed	
	2008/9	2009/10
I’ve learned how relevant science is to my everyday life	71	61
It has given me more confidence to talk about science	46	45
I intend to go and find out more about science	46	40
The information demystified science and made a complex subject easier to understand	75	68
I’m more aware of different views on current scientific issues	62	54
I learned things that I wouldn’t have thought of as science	58	44
I intend to change my lifestyle	33	19

(Morris Hargreaves McIntyre, 2011, p. 14)

It may be true that engaging with exhibits, shows and talks at science centres offers valuable learning experiences. There may be positive impacts immediately following visits. Longer-term impact of engagement with science centres in Scotland was not

explored in any of these reviews, nor is it explored in other published research. This is not atypical. Lloyd et al. (2012) identified that UK-wide, inclusion of learning in assessment of medium- to long-term impact is rare. At the time of CfE development, and at a time at which there was strong support, financial and otherwise for science learning beyond the teacher-led, the understanding of the value of these experiences in Scotland was unclear. It remains so. International research studies investigating the value of field trips to out-of-school learning settings worldwide are contradictory in their findings (Griffin, 2004). In the USA, 'informal science institutions (ISIs)' such as science centres have been established for many decades longer than in Scotland, and thus more evidence of impact is available for this context (Lloyd et al., 2012). Nevertheless a 2007 study involving 475 ISIs concluded that ISIs "have yet to determine how best to support students and teachers in terms of the actual curriculum and materials used within the classroom" (Phillips et al., 2007, p. 1505).

The last four-year strategy for the SSCN was published in 2005 (SE, 2005b). Since 2011, no further external review and evaluation of the SSCN has been published. However, the science centres are cited in the Scottish Government's most recent *STEM Education and Training Strategy* (SG, 2017c) as building science capital and being a source of promoting inspiration (Weaver, Hanks, & Staiano, 2017). From the evidence within the available reports and reviews, it is not possible to conclude that the SSCN contributes effectively to progression of learning within CfE or builds science capital. Of the little research published on CfE (Priestley & Minty, 2012), none examines whether or not there is a positive contribution of the external partners and organisations to progression of learning in science within CfE. Nevertheless, a further funding package of £2.6 million was awarded to the four science centres in late 2017, to fund increased engagement with schools and under-represented groups (Somerville MSP, 2017). The situation in Scotland is perhaps best captured by Eshach (2007) who identified a gap between the feeling that there is great potential in school 'field trips' and the extent to which this potential is achieved; we remain in the position where the benefits of science experiences are "presumed" (P. Bell et al., 2009, p. 19) .

Learner voice

In the 1960s and 1970s, research into ‘pupil voice’ (or learner voice) was vigorously pursued (Flynn, Shevlin, & Lodge, 2012) but only to the extent that it established that there was an important contribution to be made rather than as the basis for any action (Flynn et al., 2012). Educational research which **utilises** rather than simply recognises or acknowledges to voice of the learner has developed, proliferated and diversified since it emerged in the 1990s and early 2000s (Cook-Sather, 2014; Flynn et al., 2012).

In the mid-2000s, Rudduck observed that there was a “zeitgeist commitment to (student) voice” (Rudduck, 2006). Robinson and Taylor (2007) illustrated this through drawing on policy and inspection frameworks in England. Rudduck’s observation equally applies in Scotland, where listening to learners and learner voice are at the centre of CfE developments. Working with learner voice may not be as easy as its popularity suggests (Rudduck & Fielding, 2006) and there is a need for caution that work with ‘voice’ does not simply become another tool by which individuals are treated as a group, with the complexities of individual identities ignored, and through which those eliciting voices further oppress them (Cook-Sather, 2007). Working with children’s voice, I recognise that it is essential to be critical, and to reflect on the processes and my role (Spyrou, 2011). In this section I explore the challenges of working with ‘voice’ and Scotland’s pursuit of a curriculum which places the learner at the centre.

Empowerment to transformation

The national body with responsibility for quality and improvement in education in Scotland, Education Scotland, holds a vision of transformational change in professional practice and the education system, and of the transformational power of learning for people’s lives. Transformative practice requires a commitment to engaging with learner voice (Fielding, 2001a, 2001b, 2001c, 2004) and the relationship between voice and empowerment (Flynn, 2013), through a process that is credible to the children involved (Rudduck & Fielding, 2006). Work with voice is not authentic or consultative unless it can bring about real change or transformation (Flynn, Shevlin, & Lodge, 2011). To do so requires a change in roles and in the power balance between adults and the children whose voices we wish to hear (Rudduck & Fielding, 2006). Whilst there is some research

concerned with learners' views on science in school (see, for example, Jenkins, 2005, 2006) reviews of out-of-school science experiences include limited input from children (DeWitt & Osborne, 2010; Eshach, 2007). Few attempt to explore experiences from children's perspectives. Discussion with children can be used to confer a legitimacy on the process and outcomes (Spyrou, 2011). However, when children's views are sought in reviews and research in which the agenda has been set, and discussions "framed and articulated" by adults (see, for example, HMIE 2007), the children are unlikely to be meaningfully engaged beyond the "initial flush of enthusiasm" (Fielding, 2004, pp. 306-307).

Engaging learner voice is not easy (Rudduck & Fielding, 2006). Children experience "consultation fatigue" (Lundy, 2007, p. 934) and tire of the "increasing number of invitations (a) to express a view on matters they do not think are important; (b) framed in language they find restrictive, alienating or patronising; and (c) that seldom result in actions or dialogue that affects the quality of their lives." (Fielding, 2004, pp. 306-307). The issues on which children's voices are elicited reflect power differentials (Noyes, 2005) and remain within the power of the adults involved. In their study of the use of photographs and video for stimulated recall to explore engagement with exhibits in a science centre, DeWitt and Osborne (2010) recognise the limited research exploring children's perspectives. However, their attempts to involve children's perspectives are framed by adult researchers in language which is not necessarily immediately accessible to children. Children are asked to justify their ratings of how interesting they found visits, indicating to participants that their views have to be acceptable to the adult researchers. The format remains one in which those doing the consulting "have the upper hand" (Alderson, 2008, p. 143).

Adopting approaches to engaging learner voice without a careful and critical examination of issues of power and hierarchy is unlikely to realise the potential for transformation (Noyes, 2005). In a school setting, to imagine that the issue is one of unwillingness by teachers to 'give up' power is a very simplistic interpretation of a complex issue, as much involving teacher identity and teacher voice as learner voice and power (Bragg, 2007). Perhaps counterintuitively, teachers using a child-centred pedagogy, whilst not averse to the notion of learner voice, see themselves in the role as "caregivers and protectors of children, whom they saw as vulnerable and even

passive” (Bragg, 2007, p. 515). As a result, they believe that they know the views of the children and can speak on their behalf. To empower learners effectively can fundamentally challenge teachers’ perceptions and understanding of their own role and professional identity to move from working on behalf of, to working with, learners (Bragg, 2007). This challenge is also faced by those working in learner voice research: to take it from “research *on* to research *with* students” (Cook-Sather, 2014, p. 135).

Curriculum for Excellence: the learner at the centre

CfE arguably presents a radical vision of the future of schooling in Scotland (Priestley & Miller, 2012); the shift in language to include recognition of the experience of learning being the most radical and innovative element of the reform. The focus on placing the learner at the centre of learning and teaching is illustrated in a schematic guide to the curriculum framework for meeting the needs of all learners aged 3 to 18 for curriculum planners (Appendix 1) (SG, 2008). Updated national expectations for local authorities, schools, early learning and childcare settings enacted through inspections emphasise the central role of learner voice in school self-evaluation (ES, 2015).

Placing the learner at the heart of learning is part of a world-wide trend of curriculum developments, not limited to Scotland (Priestley, 2010). A focus on the learner is not in itself problematic: the “learnification of education: the translation of everything there is to say about education in terms of learning and learners” has “emancipatory possibilities...it can empower individuals to take control of their own educational agenda” (Biesta, 2009, p. 38). CfE fully embraces the ‘learnification’ of education, expanding the definition of the curriculum beyond learning planned by professional educators to encompass experiences offered by other providers. However, learning is a process which involves activities; it does not necessarily have content or direction (Biesta, 2009). There is a risk of losing sight of the purpose of education, that it matters what is learned and what it is learned for (Biesta, 2009).

Listening to learners: pupil participation in Scotland

In the period from 2000 onwards, Scotland was at the leading edge of pupil consultation and participation as a result of the structure and core principles of CfE, as well as the legislative framework in Scotland (Tisdall, 2007). Throughout the UK, the dominant

mechanism by which the voice of children can be heard in the education system is the pupil, school or student council (Sher, Gwanzura-Ottmoller, Tisdall, & Milne, 2010b, 2010c). Other methods, in use Scottish primary schools, are “notable exceptions” (McCluskey et al., 2013, p. 292).

The use of pupil councils as a forum for learner voice is problematic for a number of reasons. Across Scotland, the structure of pupil councils varies. Some are open to all, some elected and some formed by teacher selection, contributing to a feeling of exclusion among some young people (Tisdall, 2007) and concerns about the fairness of the selection processes (Sher et al., 2010b). The rush to increase pupil participation may be well-meaning. More cynically, it may be intended to demonstrate compliance with policy initiatives (Fielding, 2001a; Rudduck & Fielding, 2006). Whether it is well-meaning or simply compliant, important issues are being overlooked, including those of inclusion and exclusion (Cook-Sather, 2014; Noyes, 2005; Rudduck & Fielding, 2006). This narrows the view of pupil participation and voice (Silva, 2001), including only those voices which make most “immediate sense” rather than those which may be “anomalous”, produce “unexpected reactions” and “disrupt our assumptions” (Bragg, 2001, p. 73). It is not hard to imagine that where teachers select pupils for participation (Tisdall, 2007), or veto the appointment of pupils voted onto councils by their peers (McCluskey et al., 2013), the likelihood increases of hearing only or predominantly from voices which do not disrupt or challenge the system. The drive for greater consultation with pupils in Scotland and internationally, the construction of frameworks for carefully constrained consultation, is not to “nurture creativity, encourage greater freedom of thought and action, or usher in a genuine transformation of schools...as sites of shared power and responsibility” (Fielding, 2004, p. 103).

Emancipation and empowerment

What of the possibility of “learnification”, the ‘learner at the centre’, to emancipate and empower children (Biesta, 2009)? Drawing on the work of Humphries (1994), Fielding (2004) explores and critiques the theoretical underpinnings of “radical” (p. 295) approaches to student voice research, examining researchers’ roles in engaging student voice. Although focused on research, much of Fielding’s critique applies to what is happening in practice (see, for example, Bragg, 2001; Silva, 2001; Tisdall, 2007). Theory and practice overlap here; they cannot be separated and exploring theory allows

development of deeper and more reflexive thinking about practice (Robinson & Taylor, 2007).

Fielding (2004) discusses Humphries' notion of "accommodation of challenging and 'dangerous' (dangerous that is, to the status quo) ideas to ensure they conform to already established vocabularies and beliefs" (Humphries, 1994, p. 191 in Fielding, 2004, p. 297). Fielding (2004) describes 'accommodation' as "the defusing of potentially disruptive perspectives...one of the most insidious ways in which research undermines rather than enhances empowerment" (pp. 297-298). The effect of this is to "reconfigure students in ways that bind them more securely to the status quo" (Fielding, 2001a, p. 103; 2004, p. 302). Fielding also explores 'accumulation' (Humphries, 1994) suggesting that those researching others do so not to empower but to gather information, to 'accumulate' a deeper understanding of those being researched, to surveil, with the purpose of enabling greater control and regulation, and minimising the threat of challenge or disruption to existing, established systems and views (Fielding, 2004, p. 298). Echoing Bragg (2001), Fielding (2001a) questions whether there is a risk that mechanisms for inclusion of student voice become, if they are not already, mechanisms of control "by which the powerful are reconfirmed in their superiority and the disadvantaged confirmed in their existing lot" (Fielding, 2004, p. 303).

Among young people there is cynicism (Tisdall, 2007) and scepticism (McCluskey et al., 2013) about the process of involvement in pupil councils. Young people view participation as unlikely to lead to change (Tisdall, 2007), tokenistic (McCluskey et al., 2013; Robinson & Taylor, 2007; Tisdall, 2007) and not representative of the view of the majority within the school (McCluskey et al., 2013). Most pupils do not feel they are regularly asked for their views, or consulted by their school, and "as pupils progress through school they are increasingly likely to report that the council does not have enough power to make a difference" (Tisdall, 2007, p. 12). The cynicism among those aged 11-18 (Tisdall, 2007) is also evident in children at primary school (McCluskey et al., 2013). Such concerns are raised in other research regarding the impact of pupil participation (McCluskey et al., 2013; Tisdall, 2007); there is clearly a mismatch between the policy framework and the perceptions and experiences of pupils (Tisdall, 2007).

How has the picture developed more recently in Scotland? There is nothing to suggest any significant progress. Research conducted between 2007 and 2009 in over one-thousand Scottish schools identifies that pupil councils themselves and the adults involved with them have “high opinions of their effectiveness” (Sher et al., 2010b, p. 2). However, the majority of those who are not on a pupil council feel that councils should share more information and only a third of pupils agree that pupil councils succeed in making the school a better place for pupils (Sher et al., 2010b). This agrees with research on pupil council participation. Whilst pupils want to be involved, they are dissatisfied with mechanisms for participation, particularly “tokenistic” pupil councils which “lack in power” (Sher et al., 2010b, p. 3). It also reflects the more general concern of children in Scotland about opportunities for participation in decision-making in primary and secondary schools (McCluskey et al., 2013). In a 2013 review of health and wellbeing, a central responsibility of all Scotland’s teachers in early years, primary and secondary settings (ES, n.d.-b), it is reported that children in some of Scotland’s schools⁷ think that mechanisms for pupil participation, including pupil councils, need to be much more effective if they are to make a difference (ES, 2013a). A 2017 survey of children in Scottish secondary schools found that pupils’ perceptions of adults and the extent to which adults take into account the views of young people “worsened substantially between S1 and S5. For example, 72 per cent of respondents in S1 felt that adults generally were good at taking their views into account when making decisions, compared to 42 per cent of S5 respondents.” (SG, 2018d, p. 3). Around half of pupils in this 2017 survey reported having little or no say in how they learn, and the same proportion reported that they have little or no say in decisions affecting the school as a whole (SG, 2018d).

Research exploring how children conceive ‘participation’ identifies that it should be genuine, serve a useful purpose and make ‘a difference’ (Graham & Fitzgerald, 2010). It is not uncommon for efforts to be made to consider the organisational structure of pupil participation, whilst neglecting efforts to consider the participating pupils themselves, their role within the group and the power balances in play (Silva, 2001). Whilst “learnification” (Biesta, 2009, p. 38) has been fully embraced in Scotland, its potential for emancipation and empowerment, and for learners setting and driving their

⁷ Some is defined as between 15% and 49% (ES, n.d.-a)

own educational agenda (Biesta, 2009) is not yet realised. Remits of pupil councils vary; Sher, Gwanzura-Ottmoller, Tisdall, and Milne (2010a) note previous criticisms of the focus of pupil councils on issues which are of little or no consequence, and this is borne out both by their findings and those of McCluskey et al. (2013).

Pupil councils and school staff are least likely to identify matters relating to learning and teaching as a focus for their discussions and influence (Sher et al., 2010a). Such topics, whilst remaining “largely forbidden” (Fielding, 2001a, p. 101) areas for discussion by learners, are “becoming a legitimate focus of enquiry from the standpoint of students” (Fielding, 2001b, p. 49). Arguably, the discussion in the classroom which teachers would cite as “already listen(ing) to children” (Bragg, 2007, p. 510) does not constitute the kind of listening, the engagement of a range of children’s voices and voices used by children, which is about working **with** children rather than acting for them (Bragg, 2007). Examining the key mechanism through which ‘learner voice’ is engaged in Scotland – the pupil, student or school council – there has been a failure to understand that “facilitating student voice does not as a consequence or in isolation generate a sense of empowerment on the part of participants” (Flynn, 2014, p. 166). Scotland remains closer to the position of which Fielding (2001c) warned, developing “increasingly sophisticated ways of involving students that, often unwittingly, end up betraying their interests, accommodating them to the status quo, and in a whole variety of ways reinforcing assumptions and approaches that are destructive of anything that could be considered remotely empowering” (Fielding, 2001c, p. 124).

A theoretical framework for exploring children’s experiences and perceptions of learning science beyond the teacher-led

In science education over the past 30 years, there has been increasing attention paid to the theories of Vygotsky, in particular the frequently used but commonly misunderstood notion of the zone of proximal development (ZPD) (Murphy, Scantlebury, & Milne, 2015). Many educators have encountered Vygotsky’s work, often in a simplistic, simplified or limited interpretation without examination, exploration and understanding of the depth and meaning his cultural-historical theory (CHT) and its application to, and in, education (Gredler, 2012, 2018; Levykh, 2008; Murphy, 2015).

There are challenges in understanding and interpreting Vygotsky's work and approach, not least the lack of a single definition or understanding of his works (Robbins, 2010). This presents opportunities for the researcher to draw on the work of Vygotsky, interpreting and applying to her own unique method (Robbins, 2010). However, it is important to be cognisant of the potential pitfalls. In his relatively short career and life, Vygotsky produced a substantial body of work, much of which was translated from his native Russian only long after his death, and some of which remains un-translated. Translations of the text can be problematic with mismatches between the original text and published translations, changes of emphasis and meaning, and incorrect use and lack of quotations within the text (Derry, 2013; Veresov, 2004, 2010a, 2010b, 2010c; Zavershneva, 2012). In my research, I attempt to understand CHT through academics directly referencing Vygotsky's original work as opposed to interpreted applications within education which can present a reductionist view of Vygotsky's theory and methodology.

In 1926, Vygotsky identified the absence of understanding and explanation of individual learning and development as an international crisis in psychology (Chaiklin, 2011). He considered human development as a revolutionary or transformational process (Valsiner & Veer, 2000) and emphasised the intention of his work in psychology, CHT, as having the practical objective of educational change (Moll, 1990). In this chapter I develop and discuss a theoretical framework appropriate for understanding science learning beyond the teacher-led, drawing on CHT and exploring the use of the ZPD as a framework which leads to an understanding of how and why the children's rights-based approach is appropriate and effective in engaging children as coresearchers and research participants.

Cultural-historical theory and educational change

Many education systems, internationally, are based on the ideas of Vygotsky (Kravtsova, 2007). As countries seek to improve their educational systems there is increased interest in understanding, through Vygotsky's ideas, the connection between the individual and societal transformation (Robbins, 2010), and in understanding learning to better prepare children for the increasingly complex global context of adult life and for lifelong learning (Drew & Mackie, 2011; Tisdall, 2013). Although it is not

made explicit, CfE is underpinned in a broadly constructivist view of learning (Priestley & Biesta, 2013). As Vygotsky believed in the “societal potential” of Marxism and this shaped CHT (Robbins, 2010, p. 10), much of the language of the aspiration of CfE “to enable each child or to be a successful learner, a confident individual, a responsible citizen and an effective young person” (SE, 2004b, p. 12) foregrounds the future potential of the person and his/her role as a citizen in society (Biesta, 2008). The Scottish Attainment Challenge (SG, 2015) directs schools’ focus to transforming the lives of those living in poverty, emphasising the role of the curriculum in impacting on future society. Thus CHT and the notion of a “pedagogy...oriented not to the yesterday, but to the tomorrow of the child’s development” (Vygotsky, 1987, Vol. 2, p. 251 in Davydov & Kerr, 1995) is relevant today in the context within which my research is being carried out.

Cultural-historical theory and understanding learning

Vygotsky is recognised as the originator of the theory and methodology of cultural-historical psychology; he was critical of theories and systems built from elements of other theories and sought to identify not just theory but methodology through which to research human development (Chaiklin, 2011; Koshmanova, 2009; Yudina, 2007). The impact on education of a classical approach in psychology might be described as ‘there is nothing we can do but wait’, that is, the child is genetically destined (Veresov, 2010b). CHT differs significantly from other theories based in classical psychology: culture, environmental factors and social interaction play a key role in the development of higher-psychological functions such as logical memory, voluntary attention, conscious perception and verbal reasoning, with learning a process requiring active participation, initiative and creativity (Gredler, 2018; Koshmanova, 2009).

Elementary and higher-psychological functions can co-exist and development between them is not a natural progression, nor a gradual linear process: higher-psychological functions are new formations (Mahn, 2003) rather than being “built on the top of elementary functions, like some kind of second storey” (Vygotsky, 1930 in Veresov, 2010b). As a consequence, without exposure to the appropriate social or cultural development, an individual can go through life with lower-psychological functions, without ever developing higher-psychological functions. Vygotsky recognised that in

order to understand the development of higher-psychological functions, it is necessary to understand the source which he terms the “buds or flowers” of development of these functions (Vygotsky, 1978, p. 86). Studying retrospectively the developed “fruits” does not enhance our understanding; CHT recognises the necessity of understanding the process of development and construction of higher-psychological functions, rather than the outcomes or the product of this process (Vygotsky, 1934, in Rahmani, 1973, p. 132). In this radically different perspective (D.B. El'konin in El'Konin, 2001), psychology is not isolated from social science: it is an approach which is unique in that it “does not separate individuals from the socio-cultural setting in which they function” (Wertsch, 1985b, p. 16).

Learning science

Children’s learning in science, what is happening in terms of learning in and out of school, remains a “profound and multi-faceted” problem (Buntting et al., 2015, p. 3). Science learning is unlikely to occur during, and be attributable to, a single experience; rather it is open-ended and holistic, a cumulative result of a range of experiences in a range of contexts and settings (Tal & Dierking, 2014).

Science education, particularly school science curricula, continues to be limited by outdated views about science and the nature of science (Buntting et al., 2015). Influenced by understandings of science which have not kept pace with the rapid change in science research and learning in the wider world (Buntting et al., 2015), there is a continued vision of producing ‘mini-scientists’ which underlies school curricula (Fensham, 2015). There is overreliance, reinforced by textbooks and other school resources, on learning scientific concepts as fixed, universal entities, rather than as ideas used in different ways depending on the context (Murphy, 2015).

High-stakes summative assessment continues to be a key driver for learning in science in schools; whilst other assessment types such as ‘assessment for learning’ are used to capture science learning in classrooms, there is no evidence that they are seen as “what counts” as assessment (Buntting et al., 2015, p. 5). In Vygotskian terms, summative assessment performance indicates only past knowledge, just as a “study of human behaviour can be understood only as a history of behaviour” (Koshmanova, 2009).

Other assessment types provide opportunity to inform learning and “instruction (which) must be oriented towards the future, not the past” (Vygotsky, 1934/1962, p. 104). And yet, they do not hold equal value with high-stakes testing (Hayward, 2015). In Scotland where there has been national and large-scale innovation in relation to assessment, external assessment remains the dominant force in the senior years of secondary school (Hayward, 2015). As a result, the system privileges “pseudoconcepts” in science learning, repeatable for assessment purposes without understanding or the ability to apply them (Murphy, 2015, p. 133), and school science appears as a “living fossil” which does not provide meaningful connection between learners’ interests and the wider world (Reiss, 2015, p. 32). In the primary-school curriculum, science is included based on firm evidence of positive impact (Harlen, 2010). However, it is not immune from the narrow focus on learning driven by testing (Harlen, 2010). In the Scottish context, the dominant impact of bureaucracy on learning and teaching (Hayward, 2015) is unlikely to be lessened by the introduction of a regime of standardised testing being implemented across Scotland for children in primary and secondary schools (SG, 2017d), more than a decade after the abolition of national testing.

The majority of the literature in science education research relating to formation of science concepts draws on the work of Piaget, Vygotsky and their followers (Murphy, 2015). However, in-school learning in science continues to be individualistic rather than reliant on social interaction, and fails to recognise the culturally-dependent nature of the learning (Murphy, 2015). The steep drop-off of interest and engagement in science among children older than 10-12 years of age, despite continuing engagement with ‘formal’ education, suggests that for a continuing, lifelong interest in science and development of scientific citizens, formal learning alone is not sufficient (Falk et al., 2015). Science centres provide “positive, enjoyable, often social...highly memorable” experiences (DeWitt & Osborne, 2010, p. 1382). An important, enjoyable aspect of engagement with science offered by the informal setting is peer and social interaction (Amos & Reiss, 2012; Bamberger & Tal, 2008; P. Bell et al., 2009), offering opportunity for ‘talking science’. From a Vygotskian perspective, the importance of conversation, debate or dialogue is emphasised; greater learning is achieved in collaboration than by individuals working alone (see, for example, Murphy, 2015) with language a cultural tool through which learning is mediated, leading to the development of higher cognitive skills (Murphy, 2015).

Researchers who are engaged with learning that occurs outside of school are convinced of the engagement and learning that happens in a variety of environments (Tal & Dierking, 2014). However, research into understanding of learning in informal settings indicates that, in the main, people are guided by pragmatism and personal experience; there is little knowledge of learning theory, and among those who indicate that they use 'constructivism', little understanding of what this means (Falk et al., 2012). Current models of learning in informal settings which endeavour to connect with formal learning do not reflect a Vygotskian emphasis on learning, which would seek development through social interaction and collaboration between the adult and child (Howe, 1996). Among the various sectors within informal learning in science, none is more or less theoretically underpinned than others (Falk et al., 2012). Increasingly, however, theories which stem from cultural-historical psychology are being accepted as appropriate frameworks for understanding the nature of learning in informal contexts (Falk & Storksdieck, 2005).

Learner voice and the rights of the child

There has been much progress and growth in work with learner voice (see, for example, Fielding, 2004; Flynn et al., 2012; Noyes, 2005; Robinson & Taylor, 2007; Silva, 2001). In much practice, however, children are "silenced...(with) little or no power in the construction of accounts about them...and no avenues into the corridors of knowledge-production power" and new approaches to research are needed (Lincoln, 1993, p. 32); "voice is not enough" (Lundy, 2007).

Adopted in November 1989, the *UNCRC* "represents a worldwide recognition of children as full-fledged citizens and as subjects of rights. It also establishes States parties accountability to respect and ensure the fulfillment [*sic*] of children's rights." (UN Committee on the Rights of the Child, 2006, p. vii). Article 12 is one of the most controversial provisions (Lundy, 2007) within the *UNCRC* (UN, 1989; UN Committee on the Rights of the Child, 2009) and is of particular relevance to my research. The full text of Article 12 provisions is:

1. States Parties shall assure to the child who is capable of forming his or her own views the right to express those views freely in all matters affecting the child, the views of the child being given due weight in accordance with the age and maturity of the child.
2. For this purpose, the child shall in particular be provided the opportunity to be heard in any judicial and administrative proceedings affecting the child, the views of the child being given due weight in accordance with the age and maturity of the child.

(Lundy, 2007, pp. 927-928)

What may be considered controversial, can also be perceived as innovative. Traditionally, children have been seen as **objects** of legal protection (Mason & Cohen, 2001). In his central work about justice and equity within education (Mithra, 2014, p. 98), Freire argues for “situating educational activity in the lived experience of the participants” (Smith, 1997, 2002 para. 5). This is significant to my research accessing children’s voice to understand their experiences, and perceptions of these experiences. To liberate the silenced or oppressed, requires a pedagogy, by which Freire means “a philosophy or a social theory” (Macedo, in Freire, 2005, p. 24), and a process of “reflective participation” (Mithra, 2014, p. 100) which includes them in the process as subjects rather than objects. The adoption of the *UNCRC* moves children to being the **subject** or bearers of human rights (Mason & Cohen, 2001; Verhellen, 2001) with an emphasis on the nature of the relationships between children and adults as interconnected and not necessarily hierarchical (Roche, 1996). This can also be considered as a Vygotskian perspective: the “interdependence of individual and social processes...provides an important foundation for developing...environments that value the whole child” (Mahn, 2003, p. 120).

There is an obligation on researchers to find alternative approaches to research on and with those whose voices are silenced (Lincoln, 1993), to recognise the need for “rupture of the ordinary” (Fielding, 2004, p. 296) and for radical changes in the role of the researched and their relationship with researchers (Lincoln, 1993). Approaches to exploring voice must be examined to identify those likely to lead to transformation (Fielding, 2004). Article 12 holds the potential for that transformation (Lundy, 2007). The ratification of the *UNCRC*, framing voice in the context of rights and credited as the

driver for the move to engage children as researchers (Cook-Sather, 2014), offers opportunities for partnership between children and researchers moving beyond researchers as “distanced, authoritative, sole authors of meaning” (Cook-Sather, 2012 in Cook-Sather, 2014, p. 135).

Involving children in research

Whilst other research may be framed or driven by the *UNCRC*, Lundy’s is the first and only analysis which examines fully what the *UNCRC* means from a legal perspective, when applied to ‘voice’ research (Lundy & McEvoy, 2012). Lundy’s conceptualisation of research with an explicit-*UNCRC* frame addresses many of the concerns arising as ‘voice’ has increased in popularity, in research and in practice in schools, in particular issues around power: “rights...have the potential to be levellers: they have the ‘promise’ of **restraining the powerful** [emphasis added]” (Roche, 1996, p. 25).

There remains a gap between the UK’s commitment to the *UNCRC* and what is happening in decision-making in education in practice (Lundy, 2007; Lundy & McEvoy, 2008) with children having fewer rights than other groups and less institutional protection for these rights (Giroux, 2003). Traditionally, society constructs childhood in a way which locks children “in limbo in which they must wait and prepare themselves to be future performers” (Verhellen, 2001, p. 179), limited by the boundaries and constraints set by adults (Punch, 2004). The moves in recent years towards recognising and acknowledging that children are experts in their own lives (Clark, 2004) resonate with Freire’s work and his assertions that “a critical childhood education is interested in knowledge and intuitions children bring to school” (John, 2001, p. 142).

Despite broad international adoption of the *UNCRC*, children’s access to the rights afforded within Article 12 is limited (Lundy, 2007). In reality, access remains dependent on adults in positions of power (Lundy, 2007). The concerns of adults which hinder children’s access to their rights can be considered in three categories (Lundy, 2007). The belief that children lack the capacity to participate meaningfully (Lundy, 2007), an “ideology of immaturity” (Grace, 1995, in Rudduck & Fielding, 2006, p. 225) prevents adults from understanding that pupils are young people who are both

capable and responsible (Rudduck & Fielding, 2006). The second concern is that ceding greater control to learners will undermine and destabilise the existing structures within schools (Lundy, 2007), which are built on the notion of the child as a “subordinate subject” (Wyness, 2000, in Rudduck & Fielding, 2006, p. 225), rather than a human with full rights, the same as an adult (John, 1996). The third is a concern over whether time spent engaging with learner voice would be better spent on learning (Lundy, 2007), amplified by a lack of awareness of Article 12 and the legally binding obligation to respect children’s views (Lundy, 2007). The rights frame demands greater literacy among adults about children’s rights and the provisions of the *UNCRC* (John, 2001), and new and different conversations (Roche, 1996) through which the voices of children who are otherwise ‘silenced’ can be heard.

Article 12 applies to all matters which affect children and is not restrictive nor conservative in its scope (Lundy, 2007). However, decisions are often made that matters do not involve children’s views, without first seeking them (Lundy, 2007); thus children’s access to their rights is controlled by adults. Convenient interpretations of the *UNCRC*, such as ‘the right to be consulted’, ‘the right to participate’, ‘the right to be heard’ and ‘pupil voice’, risk diminishing or diluting Article 12 (Lundy, 2007), limiting children to involvement only where an adult deems it appropriate. Rather than empowering, such interpretations reinforce subjugation (Fielding, 2004).

Lundy (2007) conceptualises Article 12 through a methodology that reflects the legal obligations of the UK to children in making decisions about education (Figure 2.2). Developed through analysis of each specific statement within Article 12, this moves away from the ‘cosy’ language surrounding the narrative of voice to communicating “the legal and human rights imperative of Article 12 of the *UNCRC*” (Lundy, 2007, p. 932). It provides a shorthand for the lengthy and somewhat convoluted Article 12 without losing the “full import of the obligation...(or) sacrificing its scope and meaning” (Lundy, 2007, p. 933).

There are four key elements which must be considered in the implementation of Article 12:

Space: Children must be given the opportunity to express a view

Voice: Children must be facilitated to express their views

Audience: The view must be listened to.

Influence: The view must be acted upon, as appropriate.

(Lundy, 2007, p. 933)

These elements are interrelated and the process of decision-making iterative. In particular, there is overlap between space and voice, and between audience and influence (Lundy, 2007). The chronology of Article 12 is emphasised. The first stage is “ensuring the child’s right to express a view” and the second stage is the “child’s right to have the view given due weight” (Lundy, 2007, p. 933). Lundy’s methodology reflects a key strength of the *UNCRC*, that the rights enshrined are indivisible and interdependent (Mason & Cohen, 2001), and that Article 12 can be understood only in the context of the other relevant *UNCRC* articles (Lundy, 2007).

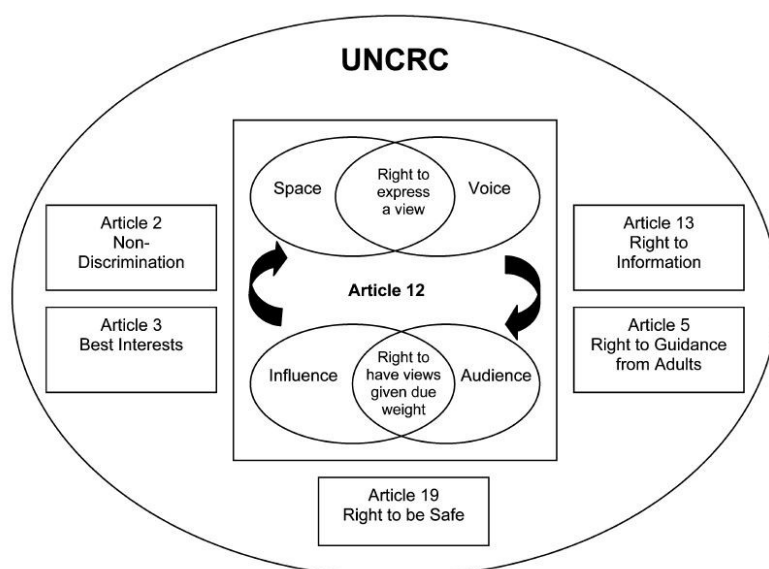


Figure 2.2 The four factors – Space, Voice, Audience, Influence – and their relationship with the main strands of Article 12 and other relevant UNCRC provisions

(Lundy, 2007, p. 932)

There has been increasing interest in understanding the implications of *UNCRC* for research processes, not only research agendas (Lundy & McEvoy, 2012). The methodology has been applied in a range of contexts including exploration of e-consultation mechanisms with children (Lundy & McEvoy, 2008), development of outcomes for educational interventions (Lundy & McEvoy, 2009) and exploring the perceptions of children on assessment in science (Murphy et al., 2010). It has been used in studies on topics as diverse as understanding youth suicide clusters (Emerson, n.d.) and children's views of conflict (McCully & Emerson, 2014).

Through its application, Lundy and McEvoy (2011) reflected upon and further developed Lundy's (2007) conceptualisation of Article 12 to consider what "an *explicit-CRC informed approach* to participation might mean for research with children" (Lundy & McEvoy, 2011, p. 3). Here the unique aspect of the approach is articulated: there is a requirement **to develop strategies to assist children, both research participants and coresearchers, in forming views, building their capacity to engage with the substantive issues being explored within the research** (Lundy & McEvoy, 2011).

A potential criticism of this approach is that strategies developed to assist children in forming views lead the children to agreement with the views of the researchers. Such strategies do require careful consideration, construction and application to ensure that participants and coresearchers are not being led to a predetermined response but are being assisted in the formation of their views through access to information and guidance from adults, consistent with their rights. Figure 2.3 illustrates the approach to research with a children's rights stance, requiring that children are given "information (Articles 13, 17) and adult guidance (Article 5) while their views are in formation, in order to be assisted in determining and expressing what will then be both a formed and informed view (Article 12)" (Lundy & McEvoy, 2011, p. 12).

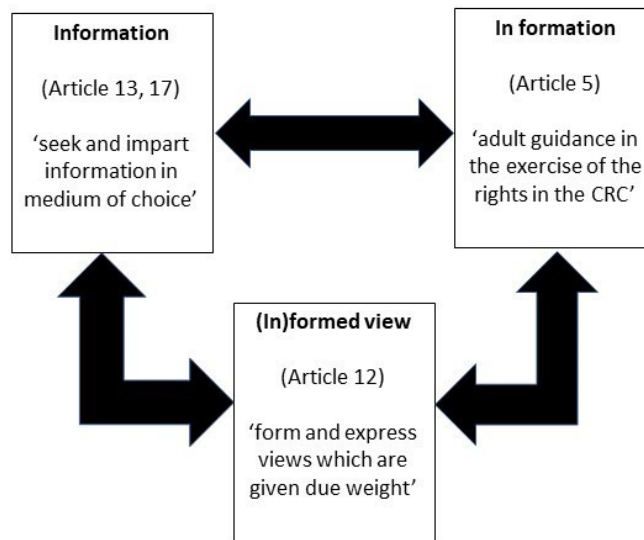


Figure 2.3 *Assisting children to an (in)formed view*

(Lundy & McEvoy, 2011, p. 13)

I answer the criticism in two ways. If people are asked to identify the most delicious meal in the world, they will likely name something they have tried before. However, if they first spend time sampling a range of foods and flavours and are asked to suggest what might make a delicious meal, we may anticipate a different response. Expanding the range of information does not lead them to an answer but ensures that they are more informed in their responses. Similarly, in local, national or general elections within democratic systems, adults are permitted to vote even if they have received information or guidance to support or guide their decision. Indeed, this is encouraged. There are concerns that less-informed citizens are more likely to vote for candidates who look appealing during television appearances (Lenz & Lawson, 2011). A number of studies evidence that less-informed people do not vote the same way as they would if fully informed (Stucki, Pleger, & Sager, 2018). Voters “want to be informed when making a democratic issue choice” and given a choice to access specific, high-quality information, four out of five voters will choose to do so (Stucki et al., 2018). Similarly, research identifies a consistent theme among children that “participation includes having access to information, so as to allow them to make informed decisions” (Graham & Fitzgerald, 2010, p. 347).

Employing this approach (Figure 2.3), there is scope to work with children as coresearchers and participants, to explore their views and insight into matters which affect them, as opposed to limiting involvement to children's lived experience (Lundy & McEvoy, 2011). This allows us to move from recognising children as experts in their own lives to including them in a greater range of issues that might otherwise be considered outside their competence and on which they may not already have considered their position (Lundy & McEvoy, 2011). Positioning adults as "potential 'enablers' capable of playing a positive role in guiding and assisting children in the formation and expression of their views" (Lundy & McEvoy, 2011, p. 14) can address imbalances in the power relationships between adults and children.

Aligning this with CHT, a consequence of Vygotsky's belief in the crucial role of culture in shaping development, is the necessity of "instruction, conceived as interaction with adults or more advanced peers" (Howe, 1996, p. 37). Participants in the children's research advisory group (CRAG) who act as coresearchers (see *Children as coresearchers: Children's Research Advisory Group* in chapter three) are not simply being asked for opinions, out of context. Learning opportunities, experiences and interaction with others provide the coresearchers and research participants with access to information to inform their views and offer the "conditions for discovering and making manifest the creative potential of students" (Davydov & Kerr, 1995, p. 13). Within CHT, it is not merely the presence of a social interaction which leads to development. Similarly, within children's rights-based methodology, it is not simply the invitation to participate which leads to a meaningful, developmental experience of participation. A process of engagement in well-planned, shared activities, can move children to a view of tasks as "joint tasks...(and) overcome the egocentricity of their own actions" (Rubtsov, 2007, p. 13), offering perspectives on issues beyond their lived experience (Lundy & McEvoy, 2011), and speaking not just for themselves but others like them.

Meaningful opportunities for the implementation of Article 12 requires a preparedness to challenge assumptions about children's capacities and to encourage the development of environments in which children can build and demonstrate capacities (UN Committee on the Rights of the Child, 2009, p. 28 para. 135). CHT and a children's rights-based perspective coincide with the idea of potential development: providing

and offering children opportunities for learning which leads their development and recognising not only what the child already is or can do, but also his or her potential. Accessing the voice of children through new research approaches, and accessing informed views on issues which might otherwise be identified as too complex by 'adult gatekeepers' with the intention of disrupting the normal practice of what it means to be an adult or a child in research, addresses concerns that methodologies involving student voice reinforce control rather than opening up the potential for transformation (Fielding, 2004).

Zone of Proximal Development (ZPD)

Vygotsky introduced into education psychology the concept of the zone of proximal development (ZPD): "what the child is initially able to do only together with adults and peers, and then can do independently, lies exactly in the zone of proximal psychological development" (Davydov & Kerr, 1995, p. 18). To engage children as participants and research subjects in ways which offer opportunities for their development through a ZPD, requires a greater understanding of this concept. The definition and practical application of the ZPD is neither straightforward nor simplistic (Levykh, 2008). Interaction is fundamental to a Vygotskian approach to learning and development (Kravtsova, 2007; Levykh, 2008; Murphy, 2012). Shared or collective activities in which children are afforded participation that is meaningful can form a ZPD which can be considered as a collaborative interaction between a child and more knowledgeable other (MKO), whether that MKO is a peer or adult (van Oers, 2007). Within the methodology developed by Lundy and McEvoy (2007; 2011) children are included as coresearchers and planned strategies are used for building the capacity to engage with the substantive issues of the research. This creates a ZPD in which children create what is done and how it is done ('spontaneous' learning), rather than this being dictated by the adult researcher ('reactive' learning) (Kravtsova, 2007). Viewing the ZPD as a two-way process in which all involved in the interactions learn from each other (Tudge & Scrimsher, 2003), offers an explanation for the benefits observed for the CRAG participants, the researcher and the research. As the participants develop confidence and a deeper understanding of the issues associated with the research, I learn from them and this learning shapes, directs and influences the research and my wider practice. The ZPD can be viewed as an "interactional achievement that allows all

participants to become teachers and learners” (Roth & Radford, 2010, p. 303); the CRAG structure enables us to become “each other’s teachers and students” independent of our adult / child roles (Roth & Radford, 2010, p. 300).

Chapter 3 Methodology

Introduction

A methodological overview of the development and application of a children's rights-based approach to participatory research to explore children's perceptions of science experiences beyond the teacher-led, and their aspirations for these experiences, is provided in this chapter. Beginning with a discussion of the terms used in the research, and a summary of the research aims and questions, an overview of the conceptual framework, identifying, exploring and justifying the research methods employed, is provided. Ethical procedures and considerations are discussed, and the data-collection process outlined. Finally, the approaches to analysis and evaluation are discussed.

Terms used in this research study

Learning science

The terms used in literature relating to learning science are many and varied (Dillon, 2013). In examining the literature and considering definitions of both the learning and the setting, I use the terms chosen by the authors of each study (Table 3.1). I define the use of terms within my study (Table 3.2) as is good practice, such that the findings of this research can be integrated with and contribute to the body of knowledge within the field (Rennie, 2014).

Table 3.1 Terms used in literature relating to learning science

Terms used in literature to describe			
Learning	Settings		Activity
Formal	Formal	Museum ⁸	Field-trip
Non-formal	Non-formal	Science centre	Visit
Informal	Informal	Informal	
Free-choice	Free-choice	science	
	Out-of-school	institution	
	Outside the classroom		

⁸ Museum is often used broadly to include science museums or centres, art galleries, zoos (Falk & Dierking, 2002), and natural history centres (Bamberger & Tal, 2007)

Table 3.2 Terms used in this study

Terms used in this study	
science experiences	Visits, field-trips, activities not led by the normal class teacher or another member of staff from the school (i.e. beyond teacher led) Excludes subset of field trips and visits where the children are out of school but interact predominantly with their own teacher or other member of staff from their own school (i.e. teacher led)
in-school science experiences	For example, led by external adults such as STEM Ambassadors, staff from higher education institutions, or as part of outreach activities by science festivals and science centres.
out-of-school science experiences	These happen in museums, science museums, science and discovery centres, science festivals, nature reserves, art galleries, theatres, botanic gardens, school grounds or immediate locality ⁹ , or the homes and communities of children.

Learner, pupil, student voice

‘Pupil voice’ or ‘student voice’ are often used interchangeably, or as alternatives dependant on age of the participant (Robinson & Taylor, 2007) or on geography (Cook-Sather, 2014). In Scotland, the term ‘learner voice’ appears in schools’ inspection and policy documents. ‘Learner’ is an all-encompassing term which refers to children and young people in schools, to young people and adults in colleges or universities, or in other settings where the terms ‘pupil’ or ‘student’ may not be appropriate, for example in early-years settings or nurseries. When referring to literature, the terms used are those chosen by the author or researcher. Otherwise ‘learner voice’ is used throughout my thesis, to align with the Scottish context, and to avoid having to use both ‘pupil’ and ‘student’ depending on the setting and age of the participant. Primarily, I adopt this term because this research is about learning, some of which may be, in Falk’s (2001) definition, ‘free-choice’. In such ‘free-choice’ circumstances it would clearly be inappropriate to refer to a ‘pupil’ or ‘student’.

⁹ King and Glackin (2010)

Research aim and questions

This aim of this research study is to explore the science experiences of children, and their perceptions of these experiences, addressing the questions:

- what are children's perceptions of science experiences, beyond those which are teacher-led?
- what do children think science experiences could do to help them learn and enjoy science more?

Research paradigm

The identification of a research paradigm is not simply a philosophical exercise. The worldview, the particular attitudes values and the beliefs held by the researcher – the ontology – shapes the approaches used and choices made to undertake and interpret research (Treagust, Won, & Duit, 2014). Locating the research within a particular paradigm provides “philosophical, methodological, and practical guidelines to design and conduct a persuasive and convincing research project” (Treagust et al., 2014, p. 13), framing the research effort including the topics studied, research design and the relationship between the researcher and participants. An examination of my ontological position and epistemological position – my stance on the nature and scope of truth and belief - is necessary to understand the philosophical premise justifying my research processes and methodology (Bracken, 2010).

Three main research paradigms can be identified in science education research (Treagust et al., 2014): positivist and post-positivist; interpretivist; critical theorist. Positivism, the application of the scientific method to the study of human behaviour and the belief in logical reasoning and verifiable evidence as a route to knowing, does not offer opportunity to understand the complexity of human nature, and in particular the human interaction involved in understanding learning (Cohen, Manion, & Morrison, 2011; Treagust et al., 2014). Similarly, post-positivism, which focuses on identification of a causal or correlational explanation for phenomena. The interpretivist paradigm emerged as a reaction against the positivist tradition. In the interpretivist paradigm a

relativist ontology and constructivist epistemology recognises that our knowledge and understanding are constructed based on context, culture and experience (Treagust et al., 2014), and the researcher working within this paradigm seeks to “understand and interpret the world in terms of its actors” (Cohen et al., 2011). Critical theorists, similar to researchers working in the interpretivist paradigm, acknowledge the social, political, cultural, economic, gender and ethnic experiences which shape our values, ideas and understanding of knowledge (Treagust et al., 2014). However, there is greater emphasis on inequality and power dynamics, and on transformations which promote freedom and democracy than would feature in an interpretivist tradition.

All social interactions are “fundamentally mediated by power relations” (Kincheloe & McLaren, 2005 in Treagust et al., 2014, p. 10). Applying an approach which protects the rights of children as coresearchers and participants, I attempt to address inequalities and issues of power imbalance within the research process. Critiquing and examining my position and my assumptions, and the relationship between myself as the researcher, children as coresearchers, and those being researched, I strive to form partnerships “based on equality of power and esteem” (Cohen et al., 2011, p. 33). These features might suggest research in the tradition of critical theory, indeed participatory research is a common research design for critical theorists (Treagust et al., 2014). Whilst drawing on elements of critical theory, in particular in relation to my epistemology, my study is situated in an interpretivist paradigm; meanings and truth are not “pregiven but are co-created through hermeneutic dialogues” (Schwandt, 2000 in Treagust et al., 2014, p. 9). I seek the views of research participants in my role as sense maker and narrator of the study (Treagust et al., 2014), to understand the meaning-making of the research participants through an evolving design. My research is a search not for proof, but for meanings and understandings of the experiences of children, and their perceptions of these experiences. At the outset of the study, it is not known what will be seen, or looked for; hypotheses will be generated, not tested, and theory will emerge.

Ethics

Approval procedures

The research conforms to the ethical standards of Trinity College Dublin (TCD), having been prepared using relevant Government of Ireland guidance (2012), and approved through the ethical approval procedures of the School of Education (SoE) at Trinity College Dublin. The research involved children, hence I identified the proposal as moderate to high risk, requiring level 2 approval (TCD SoE, 2013).

Ethical approval for research involving children requires Garda vetting (TCD SoE, 2013). My research and fieldwork was carried out in Scotland. This requirement was therefore dealt with through the Protecting Vulnerable Groups (PVG) Scheme (Disclosure Scotland, n.d.) (Appendix 2). Additionally, I have maintained professional GTCS registration continuously since 2006.

My research conforms to the relevant education authority's standard conditions of approval for undertaking research involving children (Appendix 3). Approval was sought and granted prior to work with children commencing, with an extension to the timescale for the research subsequently approved to take into account a period of maternity leave. Required approval from the Head Teachers of the school in which the CRAG was based, was granted for the relevant time period.

Information and consent

Prior to any contact between me and potential CRAG participants, information leaflets were distributed to school staff and to parents and carers (hereafter 'parents' is assumed to include carers) (Appendix 4). The leaflets included an overview of the CRAG's involvement throughout the research (Figure 3.1) and consent form (Appendix 4). All communication was via the school in order that I did not access or retain personal information about the participants.

An information leaflet was created for children invited to participate in the CRAG and distributed via the CRAG participants' school (Appendix 4). The content and design of this leaflet was developed with the assistance of children in the relevant age group. The

key ethical principles of informed consent and voluntary participation are closely linked with children's-rights standards and the rights-based approach which underpins this research (Lundy & McEvoy, 2011). Working with children to develop the literature to inform CRAG participants was intended to ensure the language was appropriate, to facilitate actively seeking voluntary, informed consent. It positions the CRAG participants as competent and capable social actors, rather than positioning parents as gatekeepers who give consent to involvement, to which the child merely assents or acquiesces (L. Phillips, 2014).

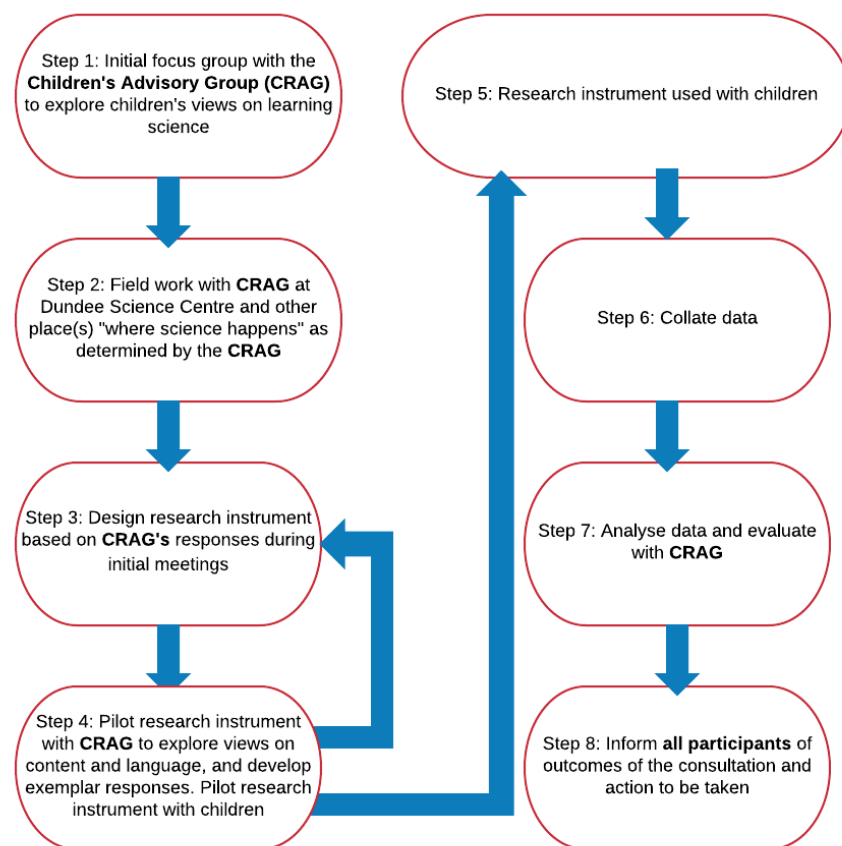


Figure 3.1 Summary of CRAG involvement in the research process included in information leaflet for parents and carers, and school staff

The design and content of the consent form for children invited to participate in the CRAG (Appendix 4) was also informed by a child in the relevant age group. The consent form was discussed with children at the first CRAG, along with the research aims and purposes, and the content of the information leaflet. This provided opportunities for

participants to ask questions and understand the implications of research prior to giving consent (Cohen et al., 2011).

All aspects of this research, including the information leaflets and consent forms conform to the ethical standards as outlined by the British Educational Research Association (2011) including

- explaining the aims of the research and providing an opportunity to ask questions
- explaining how the research will be used, at conferences and in research papers, and within a PhD thesis
- informing parents and children of their right to withdraw consent, for any or no reason, and at any time
- assuring parents of anonymity and confidentiality
- seeking permission for involvement in a series of meetings, in and out of school, at which notes will be made and discussions audio recorded.

These aspects were discussed with the children being invited to participate in the CRAG at the first meeting with me, prior to them signing the consent form. They were discussed again at each subsequent meeting of the CRAG. In particular, the voluntary nature of participation was emphasised, both participation in the CRAG and in the specific activities which they were invited to do. The children were reminded at each meeting that they could withdraw from any of the activities or from the process as a whole (Murphy et al., 2010). The information provided for parents and children in the CRAG included details of how to contact me. For parents, details of the research supervisor were included so that they may contact my supervisor regarding withdrawal from participation or for any other reason.

When the information leaflets and consent form were produced, it was intended that Dundee Science Centre (DSC), my then employer, would have involvement in and support the research study. Initial thinking was that the study would focus primarily on science centres. DSC was therefore specifically referenced in the information and their logo included. However, at our first meeting, it was clearly communicated to the CRAG that the research was an independent research study based at a university and was not

about DSC. The arrangement with DSC changed at a very early stage in the research and the study was broadened as described in this thesis.

The timescale for working with the CRAG was initially given as one calendar year. It was extended by a further 16 months as a result of a period of maternity leave. Parents, the school, the CRAG, and the relevant education authority were informed of changes to the timescale and the reasons for this change.

Ethical considerations

As approaches to engaging children aged 18 and under in substantive issues of research develop, so too must thinking on the ethics and ethical considerations of their involvement.

Exploring ethical considerations of sociological research with children, including in matters relating to education, Morrow and Richards (1996) identify two key preoccupations in relation to research ethics: informed consent and protection of research respondents. Just as children are excluded from involvement in research topics considered by adult gatekeepers as beyond their competence, discussions of ethics hinge on consent from adult gatekeepers and an understanding of children being unable to give 'informed consent' depending on their age (Tymchuck, 1992, in Morrow & Richards, 1996, p. 94). Consequently children are excluded from research agendas (Cocks, 2006).

Despite the continuing development of 'voice' research with children, the concept of voice as it relates to education research ethics is underexplored in the literature (Midgley, Davies, Oliver, & Danaher, 2014). Morrow and Richards' (1996) overview of ethics of social research with children was published over 20 years ago. And yet, research ethics procedures continue to assume children lack competency as social agents (O'Neill, 2014). A model of ethics which is taken from the position of the child and increases agency rather than focusing on children's vulnerability and lack of competence (O'Neill, 2014) is required to facilitate methodologies for exploring learner voice, and for 'voice' research to lead to empowerment and transformation.

The ethical considerations associated with this study are approached from a position in which the interdependence of the researcher and the researched is recognised, with a “careful and detailed awareness of the interaction between the persons involved” (Cocks, 2006, p. 257). Pursuing a methodology in which children are seen as competent social actors, requires “situational and responsive” ethical considerations (Morrow & Richards, 1996, pp. 102-103). Ethical frameworks and tools are not adopted simply to satisfy the process of achieving ethical approval, but rather reflect my beliefs as a researcher and the desire to address power imbalances between the researcher, coresearchers and research participants. This requirement for reflexivity places greater emphasis on me to “demonstrate (my) competence to participate within the world of childhood, than it does the competence of the child to participate in the researcher’s world of adulthood” (O’Neill, 2014, p. 228).

Research design and approach

Positivist and post-positivist researchers tend to employ quantitative approaches whilst those working in the traditions of interpretivism and critical theory employ qualitative methods (Treagust et al., 2014). My research might best be described as pragmatic. I have adopted a methodology which is “eclectic, pluralist...drawing on...epistemologies based on the criteria as fitness for purpose and applicability and regarding ‘reality’ as both objective and socially constructed” (Cohen et al., 2011, p. 23). Methodological pluralism, or mixed methods, means that rather than being wedded to one paradigm, the research can be driven by the research questions (Cohen et al., 2011). Both qualitative and quantitative approaches are used, providing richer data which can be triangulated, probed and corroborated for new thinking to emerge (Cohen et al., 2011). This presents challenges both with the methodology and for analysing, interpreting and reporting on the research in a way which ensures genuine integration of the methods. The challenge of combining the ontological and epistemological positions of different paradigms and methods, marrying objective data with constructivist meaning making to ensure that “quantitative and qualitative elements are mutually illuminating” (Bryman, 2007, p. 8) is not underestimated. However, it is worth pursuing; a mixed-methods approach offers “deep and potentially inspirational” opportunities for “respectful listening and understanding” (Greene, 2008, p. 20).

A mixed-methods approach is particularly appropriate to research in a relatively unexplored field that presents new problems and questions, for which “innovative research designs, methods and analyses are critical” (Rennie, Feher, Dierking, & Falk, 2003, p. 117). A pragmatic approach offers new techniques for gathering and analysing data with opportunities to develop new theoretical grounding as appropriate (Rennie et al., 2003), and for the “methodological ingenuity” necessary to further understanding of learning science beyond school (Osborne & Dillon, 2007, p. 1443).

Learning is learning, wherever it happens

This study aims to explore children’s perceptions of and aspirations for science experiences, beyond the teacher-led. The language of researchers around informal, non-formal, free-choice and out-of-school learning is unlikely to be used or understood by children, or indeed by adults other than those who work within these sectors.

Many science experiences could be described as free-choice (Falk, 2001), for example watching television programmes about science, or reading science magazines. Depending on circumstances, others such as visiting places to do with science with families or friends or going for nature walks (Sacco, Falk, & Bell, 2014), may or may not be free-choice.

Experiences which take place with the child’s school are key in the broad definition of CfE as the “totality of learning” wherever it happens (ES, 2015, p. 3; SG, 2008, p. 11). These may take place in venues such as science centres, venues which often describe themselves as informal settings (Lloyd et al., 2012). However, in the context of working with school groups, they might equally or better be described as non-formal settings (OECD, 2016b). The limited research evidence about the experience of children within school groups in such settings suggests that learning approaches, choice and interactions experienced by children may in fact be neither informal or non-formal; there is a tendency towards content delivery in a didactic fashion (Cox-Petersen et al., 2003). Learning in these circumstances cannot be described as free-choice. The experiences are arranged by the school, although the child may have the choice not to participate in the visit at all. The experiences within visits are planned by the school or staff from the museum or science centre.

My study is premised on the notion that “learning is learning...learning situations include classrooms, museums, zoos...each...can be formal or informal, depending on the structure of the learning opportunity and the manner in which the individual perceives the context” (Dierking, 1991, p. 4). There is no intention to compare and contrast one science experience with another. Instead, my research is an exploration of what science experiences could do to help children learn and enjoy science, with a broad understanding or acceptance of what learning is and where it takes place. With that comes the need to develop new ways of understanding or evaluating that experience (Ainsworth & Eaton, 2010).

Children as coresearchers: Children’s Research Advisory Group (CRAG)

There are many different approaches to participatory research involving children, in the context of rights and acknowledging children’s agency (Beazley, Bessell, Ennew, & Waterson, 2009). Respecting children’s rights and interests requires a greater degree of involvement in research design and delivery than is facilitated through traditional research approaches (Alderson, 2008; Lundy & McEvoy, 2012). Although not in fields relevant to my study, the growing body of research involving children throughout the research process and as peer or coresearchers (Lundy, McEvoy, & Byrne, 2011) can be drawn upon.

Fielding (2004) offers two models of engagement with children. In the first, children are researchers. The conduct and completion of the research relies heavily on the expertise and experience of the adult researcher. However, it cannot succeed without the involvement and engagement of children researching alongside adults, in particular acting as “makers of meaning” (p. 307). In the second model, children are coresearchers, skilled in research and enquiry, identifying issues for research and carrying out studies, supported by an adult: “students shape the subject, pace and pattern of the research...staff enable the practical realization of the research and support the development of the skills and dispositions of individual and group learning” (p. 307). Although elements of Fielding’s (2004) models influence my research approach, the children’s participation in the CRAG, their role as coresearchers in the study, is not entirely consistent with either of his definitions. Participation is not intended to develop the children’s research skills and values *per se*. Instead, it offers

opportunities to act as advisers, developing informed views around the issues being researched, to be able to engage in this the process fully and act beyond their existing capability. Children's active participation is consistent with cultural-historical methodology, recognising the value for personal development of situations in which the children perceive that they are not just the subject of the research process, but also the source (Kravtsova, 2007).

The involvement of children as coresearchers is increasingly common in qualitative studies (Lundy & McEvoy, 2009). It is less common in quantitative and large-scale studies (Lundy & McEvoy, 2009) such as mine. There is a need for research in informal learning with a strong methodological and theoretical grounding, connected to mainstream science education (Rahm, 2014). The use of Lundy's methodology by Murphy et al. (2010) in the Wellcome Trust commissioned research study exploring the perceptions of children of assessment in Key Stage 2 science is therefore significant. The study by Murphy et al. (2010), involving around 1000 children in primary and secondary schools in England and Wales, demonstrates the applicability of Lundy's (2007) methodology with the age group relevant for my research, for gathering large-scale quantitative and open-ended response data. It demonstrates the use of the methodology for engaging with children's voice and with children as coresearchers to explore a topic which is politically sensitive, policy linked and central to learning and teaching in school science (Murphy et al., 2010; Murphy et al., 2013).

A challenge in designing fieldwork for this doctoral research was planning interventions motivated by theoretical ideas (Chaiklin, 2011) and reflecting the cultural-historical framework. From a Vygotskian perspective, children's ideas are to be elicited, not to be challenged but to "establish a foundation on which to build new knowledge or as a point of entry into a system of relationships that are eventually to be understood" (Murphy, 2012, p. 181). The formation of a CRAG, who worked alongside me as coresearchers (Lundy & McEvoy, 2009, 2011, 2012), and engagement of children as research participants through a children's rights-based research instrument (Murphy et al., 2010) is consistent with a Vygotskian frame. Children's ideas were elicited to establish a foundation on which they could build new knowledge about the substantive issues of the research as a point of entry to understanding, and being able to advise me to better understand, the experiences and perceptions of science beyond the teacher-

led. The children who formed the CRAG were not invited to participate as research subjects, but instead to bring to the research: “contemporary experience as a child in a similar peer group as the research participants” (Lundy & McEvoy, 2011). They formed an expert group on people like them, with a remit to: advise on the research process including how best to engage with other children on the issues; assist with the analysis and interpretation of the findings; and provide insight on the main issues under investigation (Lundy & McEvoy, 2011).

Formation of the CRAG

The children invited to participate in the CRAG were an opportunistic sample. A primary-school head teacher with whom I had previously collaborated expressed an interest in involvement in projects offering new opportunities and challenges for children within the school (Appendix 5). When I identified the methodology for my research, she welcomed the school’s involvement.

I did not gather personal information regarding the children who formed the CRAG to identify, for example, ethnicity or information on indicators of relative deprivation. Situated as it is within an interpretivist tradition, is not claimed that this results or outcomes of this research are generalizable to the broader population, nor that they are representative of the aspirations, perceptions and experiences of other children who have not participated. Rather, the research is designed and approached to access the voice of participants to understand their lived experiences and assist them in forming views on the matters being researched. I acknowledge that my interpretation and findings might be informative or thought-provoking in terms of understanding of policy and practice within the broader context, even if not directly translatable into policy or strategy in science education (Treagust et al., 2014). Diversity within the CRAG provides a range of responses to which children using the questionnaire can relate, however the methods used do not aim to create a diverse CRAG. Hence, the use of an opportunistic sample is not problematic.

In the first instance, the school used a random-sampling method to identify eight children in primary 5 to be invited to form the CRAG. The reality of participatory research of this type, and a criticism of participatory and consultative research with

children, is that involvement 'by invitation' is potentially exclusive (Tisdall, 2015). All those identified and those excluded by the selection process expressed a wish to be included in the research. It was not my intention, nor appropriate within the research approach, to disenfranchise children and parents. Thus, all 11 who comprised the primary 5 class were included in the CRAG. Subsequently, two children left the school. One left at the end of the first school year, following the CRAG participants' piloting of the questionnaire. The second left during the subsequent school year. The remaining nine children in the CRAG continued meeting until they transitioned to secondary school.

In previous implementations, the CRAGs comprised eight children (Lundy & McEvoy, 2008, 2009; Murphy et al., 2013). Consideration was given to dividing the 11 children into two CRAGs, acknowledging the importance of particular care with a group of this size, to avoid developing a teacher / pupil relationship rather than the intended researcher / coresearcher relationship (Lundy & McEvoy, 2008, 2009, 2011, 2012; Lundy et al., 2011; Murphy et al., 2010; Murphy et al., 2013). Division by whether or not the children had visited a science centre was discounted as all of the children had done so. Division according to whether their science experiences had been positive was also discounted. This would have required gathering the views of the children, asking them to explain their experiences, and using my interpretation and judgement to categorise them, none of which is in keeping with a research design framed by children's-rights (Lundy & McEvoy, 2009). Thus, in my study the 11 children formed a single CRAG.

The first four meetings with the CRAG were attended by a 3rd year M.Eng Electronic and Electrical Engineering student and former pupil of mine, to bring another perspective to the work and to facilitate a more informal approach to working together. Additionally, the third meeting was attended by a research colleague from Trinity College Dublin.

CRAG meetings

Extensive discussions with my research supervisor informed planning for the CRAG meetings, and for the activities undertaken to enable participants to access information relevant to developing understanding of the substantive issues relating to the research (Lundy & McEvoy, 2011). Prior to the first meeting of the CRAG, the plans were also

discussed with Lesley Emerson (formerly McEvoy), collaborator of Laura Lundy in developing and implementing the approach to participatory research being used in this study (see Lundy & McEvoy, 2008; Lundy & McEvoy, 2009, 2011, 2012; Lundy et al., 2011; Murphy et al., 2010; Murphy et al., 2013). Following the first phase of data collection from primary schools, I also met with Laura Lundy to discuss the progress of the research and ideas for next steps.

During the period of the research in which field work was carried out, 10 CRAG meetings were held (Appendix 6). Whilst it is not unusual for children to be consulted in one-off activities, it is rare for involvement to be over a period of time and to provide opportunities for children to be engaged in dialogue (Tisdall, 2015). Documents relating to CRAG meetings were held in a file, including notes of each meeting and photographed images of artefacts. A duplicate file was held by the CRAG, to act as a reminder of meetings and activities and to facilitate addition of notes and review of their work, an approach recommended in discussion with Lesley Emerson. Sections of meetings were recorded and transcribed, not for the purpose of producing data but rather to support my reflections and inform planning for subsequent meetings. I used the recordings of early meetings to reflect particularly on the extent to which there was a balance of child / adult talk as I sought to overcome typical hierarchies and power structures (Tobin & Roth, 2006).

Space, Voice, Audience and Influence

To protect the rights of the children in the CRAG and those participating as research subjects, it is necessary to examine how to enact the four key elements of space, voice, audience and influence (Lundy, 2007), and to develop mechanisms to assist in the development of informed views (Lundy & McEvoy, 2011) for all children involved with the research. In this section, I focus primarily on the CRAG. The rights of children as participants and research subjects are further explored in the sections *Children as research participants* and *Assisting research participants to informed views*.

Space

A safe 'space' is one in which children are assured that their views are treated as confidential. The ability of children to speak 'freely' requires mechanisms which protect anonymity (Lundy, 2007). In my study, children participating in the CRAG were invited

to use pseudonyms of their own choosing, to create for themselves 'research identities' such that they could express their views freely and feel confident that contributions cannot be connected back to them as individuals (Murphy et al., 2010). Ethical concerns relating to the use of pseudonyms are recognised. Anonymising the voices of those who are not at risk, "potentially steals" those voices (Davies, 2014, p. 26). However, the decision to anonymise is closely connected to the need to assure children of confidentiality; anonymity is a key way in which "confidentiality is operationalised" (Wiles, Crow, Heath, & Charles, 2008, p. 417). At the first meeting of the CRAG, the children created pseudonyms and prepared 'conference badges' (Appendix 7) which they wore at each of CRAG meetings 1-5. The CRAG participants decided to update their badges, feeling they had outgrown their earlier choices (Appendix 8) and wore these updated badges for meeting 6 onwards.

The use of pseudonyms and the identification by the children of their own 'research identities' can be considered from a cultural-historical perspective as an important element in the benefit of participation in the CRAG. In respect of the role of play in early childhood development, Vygotsky (1978) said, "In play a child always behaves beyond his average age, above his daily behaviour; in play it is as though he were a head taller than himself" (p. 102). Vygotsky (1987) posits that learning leads development, rejecting entirely the opposing hypothesis and identifying that "instruction would be completely unnecessary if it merely utilized what had already matured in the developmental process, if it were not in itself a source of development" (p. 112). Participation in the CRAG provides opportunities to be 'a head taller'. It may not be what might ordinarily be considered 'play'. However, the children are being asked to take on a role as research advisors or coresearchers, being positioned as a group of experts in their own lives and in being themselves (Clark, 2004). They can be considered to be 'role-playing' within their research identities, until the 'rules' of the interactions become internalised. This learning opportunity leads to their development.

The environment and conduct of the CRAG meetings must be as 'un-school-like' as possible (Murphy et al., 2010). The school setting is recognised as a place where children have least opportunity to exercise their rights (Kellett, Forrest, Dent, & Ward, 2004). Adults control children's use of time and space, clothing, when they eat, and how and when they socialise (Kellett et al., 2004); "there are no spaces, physical or

metaphorical, where staff and students meet one another as equals, as genuine partners in the shared undertaking of making meaning of their work together” (Fielding, 2004, p. 309). Where possible, CRAG meeting were held in places other than school such as a science centre, and in places identified by the CRAG as ‘where science happens’ (Appendix 9). CRAG meetings within the school took place in rooms and spaces other than the participants’ classroom. Whether in a general-use room, alternative classroom or the school gym hall, there was an emphasis on using the available space to work as informally as possible. This was not perfect. The sounds of school surrounded us, and the CRAG often gathered round a table to work, think and talk, as they might in their own classroom. However, there was an emphasis on freedom and informality within the space. The CRAG participants were not constrained at desks and were free to move around as they wished, either whilst working on tasks or simply to have thinking time, personal space, or a rest from involvement.

In one activity, ‘concentric circles’, the children suggested placing flipchart pages on the floor and lying on their fronts, positioned like the spokes of a wheel, to talk and work together. In another activity, during the evaluation and analysis of data, the children moved furniture to better suit how they wanted to work. We did not adhere to breaks dictated by the school bell. Instead we discussed tasks to identify points at which a formal ‘break’ would be appropriate. During snack and break times in a number of our meetings, the children chose to remain to talk with me and together as a group.

The notion of a safe space does not refer only to the physical environment. In planning how to work with the CRAG I drew on approaches used when engaging children in cogenerative dialoguing (Tobin & Roth, 2006) which has parallels with the Lundy and McEvoy (2007; 2011) methodology. The use of small groups is advocated, such that participants can speak and be heard, with the aim of listening to the advice of children as experts and creating relationships in which the adult is not seen as an authoritative figure. At the beginning of each meeting together, regardless of venue, the freedom to withdraw fully or temporarily from the process, from any activity or part of activity was discussed. No explanation was required to do so; an aspect of the process emphasising the CRAG participants’ freedom from coercion (Bowers, 2005). I endeavoured to convey an informal tone, whilst building trust and respect. Shared break time and eating together was one element of this (Tobin & Roth, 2006). Other elements were:

sitting, not standing, when working with the CRAG; not wearing formal 'work' attire; and using language familiar to the children (Marshall, Byrne, & Lundy, 2015). I paid particular attention to verbal and non-verbal indicators that children's contributions were valued and valuable, including: building on children's ideas with further discussion; asking follow-up questions; smiling; making eye contact; using head nods and other positive body language (Tobin & Roth, 2006). I employed features of "radical listening...a respectful way to deal with others' ideas" (Kincheloe, 2011) by listening attentively to the children, identifying and clarifying key points being made and making the effort to understand their views without arguing or attempting to change these views.

Significant from a Vygotskian perspective is the idea of a "developmental social environment" (Kravtsova, 2007, p. 9), recognising the person as a social being whose development is dependent on interaction with environment (Koshmanova, 2009). The attention given to 'space' (Lundy, 2007) situates this methodology in a Vygotskian cultural-historical tradition. This is not simply about a physical place to work but a space which is "relational, creating and composed of human and material relationships" (Tisdall, 2015, p. 386). The careful consideration of the social environment or space to enable children in their learning and interactions, is both central to the Lundy and McEvoy methodology and the formation of a ZPD (Kravtsova, 2007). The activities of the CRAG do not take place "in a vacuum...they always occur in specific situations and cultural contexts...the child borrows from the competence in the room" (Strandberg, 2007, p. 16). The environment must be acknowledged as somewhere which can either enable or obstruct effective learning.

Lundy and McEvoy's methodology (2007; 2011) differs from other participatory research approaches, including those which can broadly be described as 'rights-based'. Framing in terms of the legal articulation of human-rights based approaches, Lundy and McEvoy (2012) argue that the *CRC* standards should inform research aims and the research process should comply with them. The process is constructed to form a two-way interaction, a ZPD, furthering children's rights as outcomes "build the capacity of children, as rights-holders, to claim their rights and build the capacity of duty-bearers to fulfil their obligations" (Lundy & McEvoy, 2012, p. 78).

Voice

Development and learning requires creation of conditions in which children feel that the learning is connected to their needs including safety, communication, development, success and personal power (Koshmanova, 2009, p. 16). Good practice in working with children in research requires honesty regarding the degree to which power is shared between the adults and the children involved in the project (Lundy & McEvoy, 2009). Freire's very useful and insightful discussion around power and authority in education, primarily with respect to the role of the teacher (Macedo & Freire, 1995), shaped my perspective, thinking and my role with the CRAG. Freire draws attention to the "deceitful discourse" or "distortion of reality" of teachers whose role is institutionally created masquerading as facilitators and in doing so attempting to de-emphasize and "veil their power" which they may in reality choose to exercise at any time (pp. 378-379). From the first meeting, and throughout the process, when talking with the CRAG I emphasised that my research was not 'child-led'. Upfront, I discussed with the CRAG my role as a researcher, what that means and their understanding of it, what I was trying to find out and why. I was open about constraints on the research such as timescale and methods (Murphy et al., 2010). For example, face-to-face interviews were not feasible because of my intention to seek involvement of several hundred children in the data-collection phase. I shared my intention to employ a questionnaire format and I discussed with the CRAG the extent and nature of their involvement in developing this research instrument and in the research more generally. Whilst I did not want the children to see me as somebody there to teach them or in the role of teacher, I did not attempt to cover up or mislead them on my background as a teacher. Indeed, one of my former pupils supported the work of the CRAG and we were open about our background and relationship.

Facilitating the ideas of the CRAG, bringing together the knowledge and perspectives of the children through open exploration and mutual respect, requires the breakdown of "patterns of vertical authority" (Bowers, 2005, p. 368). My commitment to achieving this is reflected in the children's rights-based approach used in my research and the relativist ontological approach which underpins my work as a teacher and researcher. In Bakhtinian terms, the opportunity for 'voice', a "freedom to think critically, and (exchange) ideas in a nonthreatening" environment, the provision of "a space for mutually informative discussion where ideas can be voiced, considered, and debate...

(crediting) students from the outset as people with knowledge to share, thereby challenging certainties of power, privilege and institutional academic investment” is “an ethical state” (Bowers, 2005, pp. 369-371). For Freire it is part of the “ethical procedures” in learning (Bowers, 2005, pp. 369-371). The power imbalance cannot be overcome simply by sincere intentions; it is possible that the children will regardless defer to ‘authority figure’. CRAG sessions and activities must therefore be carefully structured to overcome this and to create opportunities for Freirean dialogue through which children engage in “sharing, suggesting self-other experience, mutuality, interchange, assimilation, co-creation, and simultaneity” (Bowers, 2005, p. 371).

The distinctive element of the Lundy and McEvoy (2011) methodology employed in my research, working within a *UNCRC*-informed approach to children’s participation, is the recognition not only of the children’s right to express a view, but the requirement to assist and facilitate children in forming views (Murphy et al., 2010). A range of activities was carefully designed to assist the children in understanding the substantive issues of the research, “understanding experiences and perspectives beyond their own” (Lundy & McEvoy, 2011, p. 6), situating their own experiences within these wider issues, and building confidence in engaging with the research. Recognising that the children may not have given consideration or developed an informed view on the issues under examination (Lundy & McEvoy, 2011), the use of such activities does not impose on the children in the CRAG a pre-determined perspective (Lundy & McEvoy, 2011) but rather it provides them with a framework through which they can engage as coresearchers and explore the findings of the research. Recent research indicates that children themselves understand this nuance: “What can I do as I don’t know the processes? I need someone to guide me but not take away my ideas and leave me behind. (Child, 16, Asia-Pacific)” (Orr, Emerson, Lundy, Royal-Dawson, & Jimenez, 2016, p. 40).

Examining power imbalances in learning through a Bakhtinian perspective supports this approach; the sense of “oppressor and oppressed” in the relationship between adult researcher and child is overcome through child-centred discourse (Bowers, 2005, p. 372), it is legitimate to enter into a discourse with the learner, to informatively mediate learning through structured activities and opportunities for accessing “external information” (Bowers, 2005, p. 372). Research indicates that children’s capacity for decision making increases in direct proportion to the opportunities offered to them

(Lundy, 2007). The role of the adults to facilitate children's involvement is very important (Lundy, 2016). Facilitation of involvement does not lead children to agree with the views of the researcher. In a Vygotskian sense it supports them in their learning, to lead to development and 'becoming' coresearchers: "I cannot manage without another, I cannot become myself without another" (Bakhtin, 1984, p. 287).

Audience

The 'right of audience' is "a guaranteed opportunity to communicate views to an identifiable individual or body with the responsibility to listen." (Lundy, 2007, p. 937). Working face-to-face with me over a two-year period provided such opportunity for the children in the CRAG. They were able to see for themselves the ways in which their views had been taken on board, and evidence that they had been listened to with respect to how meetings operated, places we visited together, development of the research instrument, the direction of the research and how progress was communicated to research participants, schools and local authorities. The four elements within Lundy's conceptualisation of Article 12 overlap significantly. Working with the CRAG, audience is intertwined with voice and space. Children have the right to have their views listened to. The requirement for adults to 'actively' listen, observing verbal and non-verbal cues and adjusting expectations for the age of the children involved (Lundy, 2007) are also considerations relevant in the creation of a safe space in which views can be expressed. The requirement to show patience when working with children and to be creative in adapting activities and expectation to facilitate the children's preferred ways of communicating (Lundy, 2007) is also considered within voice, when identifying how to support children in developing and expressing an informed view.

The CRAG participants created videos to tell research participants about the progress of the research, what had been done with their contributions, and also to tell others about their experiences of being in the CRAG and involved with research. These videos were shared with the relevant local authority research department, as agreed within the ethical approval, and with the Head Teachers of schools attended by research participants. I identified secondary schools to which research participants may have progressed and asked Head Teachers of those schools to make available an opportunity for research participants to watch the videos.

Influence

This aspect of enacting children's rights in participatory research is the most neglected of the four elements conceptualised by Lundy (2007). Much of the research involving children focusses on voice rather than the requirement within Article 12 to ensure that children's views are given "due weight in accordance with their age and capacity" (Lundy, 2007, p. 937). Whilst it is relatively easy to consult with children and appear to listen, it is more challenging to take on board children's views and evidence the impact or influence of their participation. From the perspective of the CRAG, 'influence' aligns closely with 'audience'. At each meeting children were told what decisions had been made as a result of our work together and how their views had been taken into account. The reasons for actions were explained and where children had concerns or questions these were discussed openly, conveying to the CRAG that their views were "not just valued and respected but...integral and embedded within decision making" (Lundy, 2007, p. 937).

Influence is the aspect of Lundy's methodology which has most concerned me. How do I assure children participating in the CRAG and those who complete the questionnaire of 'influence' in a self-funded research study? This is examined further in discussion of the development and use of the research instrument (see *Research Instruments*). Influence of the CRAG and research participants has come through sharing the research work at international conferences, and through research seminars and professional collaborations. Schools in which research participants were based requested summaries of the research to inform their practice and curriculum development, and these were provided on conclusion of the thesis. The contribution of children as coresearchers and research participants has significantly influenced my practice in my role as a teacher educator in higher education (see *The personal journey to and through the thesis*). It underpinned my role leading the development of an innovative teacher education programme, unique to Scotland, and the evaluation of that programme through applying the 'voice' methodology to access the informed voice of students.

Building the capacity of CRAG participants: activities enabling access to information to inform views

Activities through which children access information to inform views must be designed to encompass the “many ways in which the pupils choose to express their feelings or views” (Robinson & Taylor, 2007, p. 6). Such activities must recognise the time, context and role dependent changes in individual voice (Juffermans & Van der Aa, 2013) as well as the differences between social and individual voices (Bakhtin, 1981, 1984 in Dong & Dong, 2013, p. 163). ‘Voice’ is not restricted to only the spoken word, nor does ‘voice’ imply that it is only through the chosen words that meaning can be conveyed. Insight into the perspectives and worldviews of the children was also gained through the “style, qualities and feelings conveyed by the speaker’s words” (Robinson & Taylor, 2007, p. 6) where each word conveys meaning, both intended and unintended (Bakhtin, 1981, 1984 in Dong & Dong, 2013). In keeping with a rights-based approach, activities were designed to be safe, inclusive and engaging, flexible and responsive to the children’s needs (Lundy & McEvoy, 2009). Optionality was emphasised throughout. Using approaches in which children are required to take turns to speak silences children as much as not creating opportunities to speak (Macedo & Freire, 1995).

The use of activities which provide opportunity to develop informed views and build confidence in engaging with the research (Lundy & McEvoy, 2011) is consistent both with a children’s rights-based perspective and with a cultural-historical framework. Guidance comes from Vygotsky’s work and his attention to mediation of learning (Chaiklin, 2012). A requirement for promoting child development and hence learning is to have “well-thought out and organised events, based on varied forms of communication between children and adults” (Kravtsova, 2007, p. 8). Vygotsky recognised the challenge of identifying effective ‘activity’ to lead to development, describing as an ‘art’ (Davydov & Kerr, 1995) the ability of the adult involved to place the activity of the learner at the core of the process of learning, and to direct and regulate this activity. Unquestionably, it is easier to talk about effective adult-child interactions in research as the foundation of successful learning or discovery, than it is to design interactions in a real situation (Rubtsov, 2007).

The development of activities used in my research was informed by discussion with Lesley Emerson¹⁰. Activities included discussion questions, prompted by images and artefacts. Examples of these and of children's responses are included in Appendix 9. During the activities, the children talked in pair and small groups, and as a whole group. They were invited to capture their thinking by talking, in writing, by scribbling, by drawing or by modelling with plasticine. The choice about the medium through which they shared their views is in keeping with Article 13, protecting the rights of children to freedom of expression (Lundy, 2007). It recognises that there is potential to alter the power dynamics and the typical or expected dynamics of conversation between adults and children using drawing, modelling and expression via visual media (Wall, Higgins, Hall, & Woolner, 2013).

The CRAG participants are invited to speak not just for themselves but for others like them, and to consider perspectives beyond their own immediate experience. To assist them in this process of moving from the subjective to a more objective stance, I employed a cultural tool: 'concentric circles' (Murphy et al., 2010). CRAG participants were invited to use this tool to consider 'how does science affect: me; my friends; my family; my school; my community; Scotland and the Scottish people; the world and all people?' (Appendix 9). Are children 'able' to comment meaningfully on effects on others, including the wider community, country and world? From a children's-rights perspective, the answer is a resounding 'yes'. Even young children are "competent meaning-makers in their own lives" (Lundy et al., 2011, p. 716), "active members of families, communities, and societies, with their own concerns, interests and points of view" (UN Committee on the Rights of the Child, 2005, p. 3) and have the right to express their views, without judgement of whether that the view is 'mature' (Lundy, 2007). This aligns with a cultural-historical perspective in which the contribution of each child, at his or her own level, to the collective or shared activity is valued (Davydov & Kerr, 1995).

¹⁰ see Emerson, Lloyd, Lundy, Orr, and Weaver (2014); Emerson, Orr, and Connolly (2014); Lundy and McEvoy (2008, 2009, 2011, 2012); Lundy et al. (2011)

Children as research participants or subjects

The methodology developed by Lundy and McEvoy (2007; 2011) provides for the protection of the rights of the children participating as research subjects through completion of the questionnaire.

Space and voice

A safe space in which children can speak freely was created by assuring children of their anonymity (Lundy, 2007) through use of an introductory video for children (Appendix 10) and information on the cover page of the questionnaire (Appendix 11). Children were also assured, in a section of the introductory video presented by a child in the relevant age group, that the questionnaire is not a 'test'; it is about their opinions, what **they think** (Murphy et al., 2013).

The distribution of the video **invitation** to participate was through schools, a shortcoming in terms of implementation of the children's rights-based approach given the constraints on children's rights within school settings (Clark, 2004). However, the decision was made to issue the invitation to participate as a video to remove the sense of obligation to me as a researcher that children may feel if I came into their classroom in person and invited their participation. It was also intended to overcome the need for reading lengthy instructions which may discourage participation. Advice was issued to the schools about the voluntary nature of participation. Staff involved were asked to convey this, and not to use the questionnaire as a task which must be completed. It was emphasised that children were under no obligation to participate, and those who chose to do so, could choose to complete any or all of the questions. Staff were requested not to prompt or 'correct' children's responses.

A large-scale questionnaire study carried out with 4754 13-14 year olds in state schools in England (Strange, Forest, Oakley & The Ripple Study Team, 2003) led to an examination of the influence of social context on questionnaire completion. Strange et al. (2003) identified that the difference between completion rates for participants briefed by researchers and those briefed by teachers within the school was not significant. Within my research, I have assumed that all schools followed the instructions given and used the video to invite children's participation in the research.

The issue of confidentiality and anonymity is a key concern for children participating in research studies (Murphy et al., 2013). Strange et al. (2003) indicate that where the briefing is carried out by a teacher rather than the researcher, a greater number of participants express concerns over confidentiality, with a highly-significant difference in the number of researcher-briefed and the number of teacher-briefed participants expressing such concerns. The difference in the number of researcher-briefed and the number of teacher-briefed participants indicating a lack of understanding of the aims of the research and rationale for the questions, is also significant. These two findings from Strange et al. (2003) validate the use of a researcher briefing of participants. Whether the briefing via video used in my study is as effective as briefing in person is not known. However, the decision to do so was based on the appropriateness of this for a children's rights-based methodology.

In keeping with a rights-based methodology, participants are entitled to assistance and information in forming their views (Lundy & McEvoy, 2011). Using their knowledge of the issues being explored with the research, the CRAG participants developed 'sample responses' to provide a "comprehensive range of perspectives" (Murphy et al., 2013, p. 592) for consideration by participants completing the questionnaire. Participants were asked to tick the statements with which they were in agreement. This was not for the purpose of gathering data on agreement or otherwise, but to encourage engagement with the range of perspectives presented before they were asked to formulate and express their own thinking in response to open-ended questions. Over 90% of participants in Murphy et al. (2010) indicated that this approach, including 'sample responses' from peers was helpful in supporting research participants in forming their own views.

Just as participation in the CRAG creates a ZPD for those involved, the inclusion of a range of perspectives to support children's thinking about the open-ended questions is a collaborative interaction between the child participant and MKOs (van Oers, 2007). In this case the CRAG participants who have had the opportunity to develop their understanding of the issues surrounding the research acted as the MKO (Tharp & Gallimore, 1988) for research participants. Thus, the methodology applied both protects the rights of the research participants and creates a ZPD for research participants. The importance of language and social interaction for development is

emphasised in a Vygotskian perspective (Mercer, Dawes, Wegerif, & Sams, 2004). As research participants read the range of perspectives, they experienced a “language-based, social interaction” (Mercer et al., 2004, p. 373), helping them to make sense of the open-ended question and developing their thinking to formulate an informed view.

Audience and Influence

These two closely-related elements are not immediately obvious in their manifestation when working with research participants via questionnaire. There exists a tension between scale and the value of dialogue when exploring issues through a participatory approach. Face-to-face dialogue between rights holders and duty bearers gives participants a greater sense of the ‘audience’ and ‘influence’ although it is not itself entirely unproblematic in its implementation and use (Marshall et al., 2015). Direct contact between the research participants or subjects and those with responsibility for giving children’s view “due weight” (Lundy, 2007, pp. 927-928) is endorsed explicitly by the Committee on the Rights of the Child (Marshall et al., 2015). This does not necessarily require face-to-face meetings between rights holders and duty bearers. A challenge for a larger-scale study where face-to-face contact with participants is not feasible is to replicate the positive aspects of such contact, as far as possible and as far as they are relevant to the participatory process and the age group involved. For example, children’s desire to be listened to and taken seriously is more easily established in person when they can observe the verbal and non-verbal cues of the duty bearers, to establish whether there is respectful engagement (Marshall et al., 2015).

In implementing the right to be heard: “participation must be transparent and informative, respectful, relevant, and accountable” (Marshall et al., 2015, p. 377). The invitation to participate issued in a video format provided an opportunity for me to ‘speak to’ participants, and for them to “put a human face... a real person at the end of the information collection process who will actually be listening” (Marshall et al., 2015, p. 364). Along with the written information, this was intended to be transparent and informative about the purpose of the research, and to communicate respect for the participants’ views. This approach recognises the importance of the children feeling they are talking to the ‘right’ person who will take their views seriously. A requirement for relevance does not preclude seeking children’s views on matters that they may not

immediately identify as relevant to their own lives. However, it requires that meaningful opportunities are put in place for children to discuss issues that they may themselves identify as important (Marshall et al., 2015). Open-ended questions, and in particular the free-response space on the final page of the questionnaire, provides such an opportunity for the research participants (Appendix 11). Thus, the methods are put in place to satisfy the 'audience' element of Lundy's (2007) methodology by using alternative methods for 'direct contact'. The research participants' responses have immediate influence as they are at the heart of the research, and a more wide-ranging influence on my understanding and perspective in my role as a teacher and teacher-educator.

Research Instruments

The remit of the CRAG included advising on how best to engage with other children on the issues being researched (Lundy & McEvoy, 2011), identifying themes to be explored within the research by providing insight on issues relating to the research questions, and co-designing the research instrument (Murphy et al., 2010). At the CRAG's first meeting, I clarified that the research instrument would be a questionnaire, used in hard copy. The limitations of this traditional approach are recognised and the benefits of using a wider range of more participatory approaches for research participants acknowledged (Kirby, 2001). The approach was chosen partly for pragmatic and logistical reasons. Using the questionnaire in an online format would have been beneficial in creating 'space' (Lundy, 2007) and assuring participants of anonymity (Murphy et al., 2013). However, it was rejected as an approach for my research because of known accessibility and technical difficulties in ICT and internet access in schools (see, for example, Cornelius & Shanks, 2016; ICT in Education Excellence Group, 2013), and the consequent burden such a demand on ICT would place on schools. Removing the constraints of, for example, booking a particular ICT slot within a resource area in the school offered greater flexibility to teachers administering the questionnaires with children, and to the children completing them.

Using interviews, role play, or other face-to-face mechanisms for gathering data was not possible given the scale of the study and the intention to involve several hundred

participants. The use of a questionnaire was also motivated by the wish to apply a children's rights-based methodology to a larger-scale study incorporating qualitative and quantitative approaches. The use of quantitative approaches is an area of participatory research in which caution is advocated (Matthews, 2007) and which is less well developed than qualitative methodologies (Lundy & McEvoy, 2009).

Engaging with research to developing informed views: comparing research instruments

As part of the activities designed to enable participants in the CRAG to engage with the issues being researched (Appendix 9), the CRAG participants critiqued questionnaires used in research with children (Murphy et al., 2013; Schreiner & Sjoberg, 2004) (Appendix 12). The *ROSE* (Relevance of Science Education) survey was chosen as one of the research instruments for consideration because it was used internationally, and on a large scale. The results of the survey were influential in the narrative around science education in Scotland, where the survey was extended to include additional cohorts of learners (Farmer, Finlayson, Kibble, & Roach, 2006; Finlayson & Roach, 2007). The *Braintastic* survey (Murphy et al., 2010) was chosen because it is a children's rights-based research instrument designed for use in a study with almost 1000 children in the relevant age group. The CRAG also considered a draft questionnaire (version 1) (Appendix 13) for my research study. This first draft was developed from reflections on the CRAG's first meeting and in discussion with my research supervisors. Incorporated were themes for the questionnaire content emerging from these early discussions and from consideration of the wider literature and research.

The CRAG participants discussed aspects of the questionnaires they thought were good, and those they thought could be improved (Appendix 12, 13). They valued use of colour, readable font size, and inclusion of images and pictures. They noted as an issue the inclusion of "too many questions". The CRAG participants emphasised the need for accessible language appropriate to the age group, avoiding language which might be termed "restrictive, alienating or patronising" (Fielding, 2004, p. 307). The title of the *Relevance of Science Education (ROSE)* survey (Schreiner & Sjoberg, 2004) was identified by the CRAG participants as an example of inaccessible, inappropriate language. Unable to understand the title, they did not understand the purpose of the survey and could

not ascertain whether they would be interested in completing it. The *ROSE* survey was intended for children aged 15 so it is perhaps unsurprising that some of the language was not accessible by the younger CRAG participants. However, this identifies a critical issue when designing and working with research questionnaires; language must be appropriate and accessible by those participating in the research.

Questionnaire themes, content and design

Development of the questionnaire was an iterative process involving the CRAG participants and working closely with my research supervisor. The themes on which the questionnaire should focus emerged through discussion and activities. The CRAG participants identified that science experiences beyond those which are teacher-led should help participants enjoy and learn science and should impact on how participants feel about science. These themes were incorporated along with questions identified in collaboration with my research supervisor and drawing on literature and policy documents relating to my context.

In response to the CRAG's discussion regarding the length of the first version of the questionnaire, subsequent versions included fewer questions, with increased focus on issues most pertinent to the research questions. With each iteration of the questionnaire, the language and layout were revised.

At the fourth meeting of the CRAG, each participant was provided with all of the pages of the questionnaire in colour. To facilitate discussion, they were not joined as a single document (Appendix 14). The CRAG participants decided that each of them would complete each page, talking, discussing and asking questions as they did so. Completion of the draft questionnaire by the CRAG participants is not data but rather serves to advise the research process (Murphy et al., 2013). The process led to in-depth discussion of the layout, content and wording of the questionnaire (Appendix 13) and to a significant number of changes which were incorporated into subsequent versions of the questionnaire.

The questionnaire (version 11) in use with research participants reflects the CRAG participants' emphasis on the need for colour and images (Appendix 13). The CRAG

participants drew and labelled a variety of images that represented science for them. Also included were some of the models made in response to the 'what is science?' activity undertaken at the first meeting of the CRAG (Appendix 9). The questionnaire was designed in LucidChart software to enable me to develop a questionnaire which reflected the CRAG participants ideas for design, images, colour and layout.

Equal space for each question avoids any suggestion to the research participants of a hierarchy of questions. In particular, providing limited space for the 'free-response' might suggest tokenism. The front cover and categorisation questions were presented separately with a more appealing layout for each, more helpful instructions about the questionnaire and more support for completion of the categorisation questions, in response to the CRAG participants' feedback (Appendix 14).

As the focus of the research broadened, the final questionnaire was not limited only to 'science centre experiences'.

Assisting research participants to informed views

The questionnaire used with research participants comprised seven questions. Four were closed, inviting participants to respond based on their own direct experience. These did not therefore require structures to assist in the development of informed views (Murphy et al., 2013). Three questions were open-ended and subjects about which the participants may not have already formed a view: "how do your science experiences make you feel about science?"; "what could science experiences do to help you enjoy science more?"; "how can science experiences help you learn?".

The open-ended questions reviewed and completed by the CRAG participants at the fourth CRAG meeting included a format for suggesting what children 'like them' might say in response to these questions (Figure 3.2). The provision of a range of responses for research participants to consider was intended to assist them in developing informed views. Sample responses were created for the final questionnaire by reviewing responses for common themes and drawing them together and in some cases directly quoting the CRAG participants' statements. This process is illustrated in the annotations on the CRAG participants' trial questionnaires (Appendix 14). These sample

responses were also informed by the discussion in CRAG meetings and during activities undertaken by participants. Prior to the questionnaire pilot, the sample responses were reviewed by my student colleague, who was present at CRAG meetings 1 – 4. The sample responses were attributed using names using names that were discussed with the CRAG for appropriateness and were not gender specific, for example Pat, Jo, Sam, Charlie (Murphy et al., 2010).

In developing the questionnaire, a number of different models for the open-ended questions were considered including a 'comic strip' and use of hand-drawn faces with the speech bubbles. Each of these ideas is largely untested in literature and considered problematic for a variety of reasons including issues around representation, diversity and interpretation.



Figure 3.2 Format for CRAG to suggest responses to assist research participants to informed views (questionnaire version 4 of 11)

Questionnaire pilot

The questionnaire was piloted with 42 children aged 10 (n = 18) and 11 (n = 23) in a PKC primary school not otherwise involved in the research project (Appendix 15, Appendix 92

16). Reviewing the questionnaires completed in the pilot, I identified an issue with the open-ended question response length. The sample responses were short sentences or single words and the pilot responses tended to be similarly brief, with one-word responses and short sentences appearing frequently. Examples of responses to the question about enjoyment were: “interactive games”, “fun things”, “do experiments”; and to the question about feelings were: “smart”, “good”, “amazed”, “happy”. Presenting an ideal through which participants can learn by modelling is a pre-requisite for formation of a ZPD (Veresov, 2004). Consequently, the sample responses were adapted into fewer, longer responses. Reformatting the statements involved a degree of interpretation of the category or theme of each statement, with such interpretation being subject to my own values and beliefs (Fielding, 2004). Hence, the reformatted responses were reviewed by the CRAG participants at the fifth CRAG meeting, to ensure that the perspectives presented accurately reflected what they had said.

Data Collection

Early in the study, consideration was given to using the research instrument with children visiting a science centre either with family and friends or as part of school group. However, there was a risk of an impact of the awareness of being studied on behaviour, the Hawthorne effect, leading to children in the science centre setting feeling obliged to agree to participate and to respond positively. A systematic review by McCambridge, Witton, and Elbourne (2014) identified the Hawthorne effect as being real but, with little known about the mechanisms or magnitude of the effect, it is not possible to identify how it might be overcome. Participants may also have questioned the degree to which their anonymity would be protected. I was concerned that the range of staff in a science centre setting may not have been sufficiently consistent in the message about the purpose of the research, nor in their approaches to protecting children’s rights.

Identifying primary schools through which to issue invitation to participate

In the first instance, the Head Teachers of 24 primary schools (Appendix 17), in four geographically-convenient local authority areas were contacted via letter or email (Appendix 18). The methods of identifying this opportunistic sample of schools are

shown in Table 3.3. One further school was included through direct contact with a class teacher who expressed an interest in participation and approached the Head Teacher on my behalf. I did not have face-to-face contact with participating children in the identified schools as part of or prior to this research.

I did not seek to underpin my research study with a focus on socio-economic status (SES). The primary measure used in Scotland to identify differences in SES, applied regionally by postcode, is the Scottish Index of Multiple Deprivation (SIMD) (SG, 2016). However, the limitations of the SIMD are well-recognised, including that it does not reflect that there may be affluence in broadly 'deprived' areas and vice versa (see, for example, Fischbacher, 2014; Nunes et al., 2017; Weedon, 2014). There are pros and cons in any available measure of SES (Weedon, 2017) and I did not intend within this study to focus on this as an area of interest. Like the labels of formal, informal and non-formal learning, 'deprivation' is a label applied to children and areas and in my study the intention is to explore the children's experiences.

Within the timescale, 11 of the 24 phase 1 schools responded (Appendix 17). Of these, one required further local authority approval. This process was not completed in time for the school's inclusion in the study. Another school requested and received a copy of the relevant local authority approval letter but did not thereafter confirm participation.

It is recognised that the primary schools responding may have done so for a particular reason, such as a focus on science in the school development plan. Those failing to respond may have held the view that children at the school would be unlikely to be interested in participation. This raised a concern that there may be bias in the sample, possibly excluding children who may have been less likely to take up the invitation to participate. The reasons for non-response were explored with a Head Teacher from one of the schools from which no response was received. This Head Teacher indicated likely reasons for non-response from seven of the schools (Appendix 17), leaving only six schools for which reasons are not known.

Table 3.3 Methods of identifying participating primary schools

Local authority	Number of schools	Identification method
Angus	1	Member of staff aware of the research expressed interest in involvement
Dundee	4	Participation in partnership science project for which I designed learning experiences for children and teachers.
Fife	3	Participation in partnership science project for which I designed learning experiences for children and designed and delivered professional learning for teachers.
Perth and Kinross (Phase 1)	17	Single high-school cluster (16 schools) - previous collaboration with staff from a number of schools within the main cluster. One additional primary school included is not directly a member of the same high-school cluster, but its wide geographical intake means it is, for some purposes, included as such.
Perth and Kinross (Phase 2)	1	Previous participation (P7, 2014/15) in questionnaire pilot; children who participated no longer at primary school.

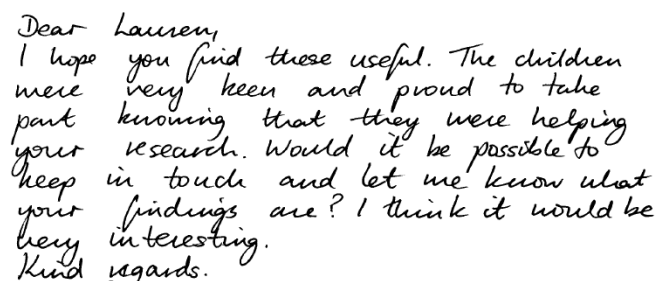
As schools responded, confirming the number of questionnaires required for the relevant class(es), they were provided with: sufficient hard copy questionnaires; a pen drive containing the introductory video and all relevant files; a transcript of the video including additional information for teachers; a protected online link to the introductory video; a self-addressed, pre-paid envelope for return of completed questionnaires.

In this first phase of data collection, over 90% of questionnaires were returned completed. The breakdown of the number of questionnaires requested by school (n = 476) and the number of completed returns received (n = 429) is shown in Appendix 17. Schools were requested to return blanks. Not all did but some indicated reasons for non-completion. However, the completion rate is calculated as a percentage of questionnaires sent out.

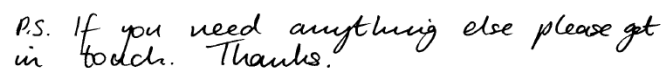
The use of approximately 500 questionnaires in the first phase of data collection involving children aged 8 to 12 in primary schools balanced the need for robust statistical analysis with the demand of processing three open-ended questions and one

‘free-response’ space. Subsequently, in a second phase of data collection, a further 110 questionnaires were issued to one PKC primary school, with a 93% (n = 102) return rate. The overall return rate from primary schools, over the two phases of data collection, was 91%.

Returning the questionnaires, two schools commented on the opportunity to participate. One indicated that participation had been the stimulus for interesting discussion and sharing of experiences and the other commented on how the children felt about participation (Figure 3.3).



Dear Lauren,
I hope you find these useful. The children were very keen and proud to take part knowing that they were helping your research. Would it be possible to keep in touch and let me know what your findings are? I think it would be very interesting.
Kind regards.



P.S. If you need anything else please get in touch. Thanks.

Figure 3.3 Note from school included with completed questionnaires

Identifying secondary schools through which to issue invitation to participate

The identification of secondary schools was opportunistic (Table 3.4). Engaging secondary schools was challenging. This was perhaps reflective of several well-publicised issues impacting on secondary schools and teacher workload at the time. School ANG02 did not respond to the invitation. School PKC18 indicated an interest in participation but did not respond to further contact (Appendix 19). In one case (school FIF05), children in the relevant age group were already participating in another research project and it was felt the additional involvement would be too demanding of staff and pupil time.

Table 3.4 Methods of identifying participating secondary schools

Local authority	Number of schools	Identification method
Angus	1	Member of staff aware of the research expressed interest in involvement
Edinburgh	1	Previous personal and professional relationship with the school.
Fife	2	Participation in partnership science project for which I designed learning experiences for children / designed and delivered professional learning for teachers.
Perth and Kinross	1	Single high-school cluster. Previous collaboration with staff from a number of schools.

Inviting children to participate in research

The invitation to participate in the research was issued to children in the schools via a short (1.5 minute) video, scripted, recorded and edited by a 10-year-old (Appendix 10).

Questionnaire returns

Figure 3.4 illustrates the local authority areas through which the invitation to participate in the research was distributed. Geographical adjacency is shown by touching borders. The area of the circles correlates with the number of participating schools.

In total, 92% (n = 1043) questionnaires were returned, either fully or partially completed. The return rates by sector are shown in Table 3.5 and the gender breakdown of participants is shown in Table 3.6.

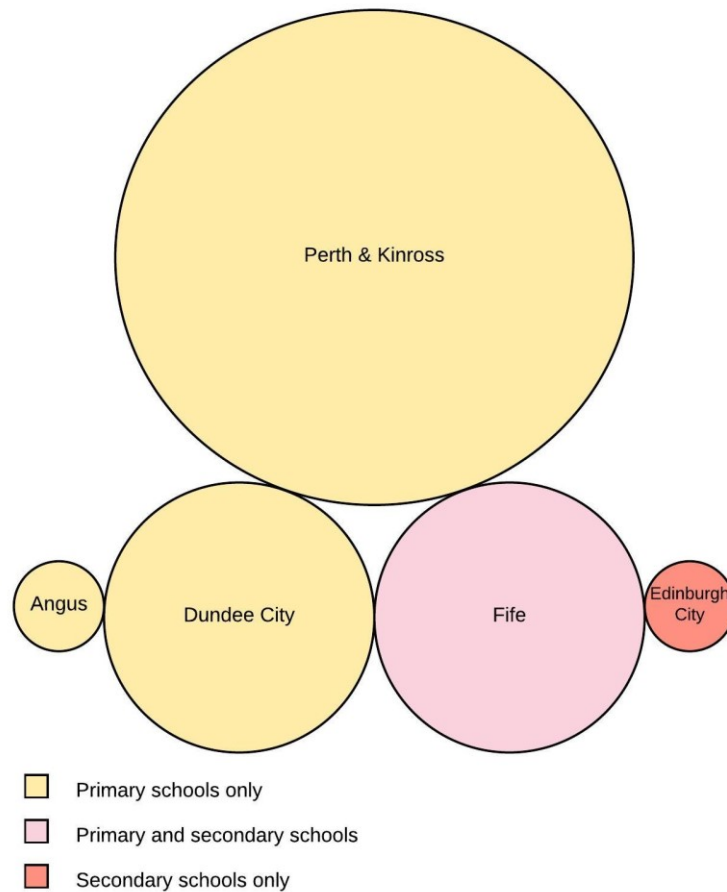


Figure 3.4 Geographical spread of schools through which invitation to participate distributed

Table 3.5 Primary-secondary sector breakdown of questionnaire returns

	Number of questionnaires requested	Number returned fully or partially completed	% returned fully or partially completed
Primary school	n = 586	n = 532	91
Secondary school	n = 553	n = 511	92

Table 3.6 Gender and sector breakdown of participants

	% of primary-school participants	% of secondary-school participants
Male	51 (n = 269)	53 (n = 270)
Female	49 (n = 259)	45 (n = 232)
No gender declared	< 1 (n = 4)	2 (n = 9)

The most recent census carried out in Scotland (National Records of Scotland, 2011) records the population split for 0 – 15 year olds as 51% male and 49% female. The questionnaire participation closely corresponds to the percentages in the Scottish population, although less so in secondary than primary. Figures 3.5 and 3.6 show the number of participants by age, sector and gender. The CRAG participants initially designed a research instrument intended for children aged 8 – 12 years. After the initial data analysis and evaluation by the CRAG, data collection was extended to include pupils in the first two years of secondary school, extending the age range of participants up to 14 years of age. More than 98% of respondents were aged 9 – 13.

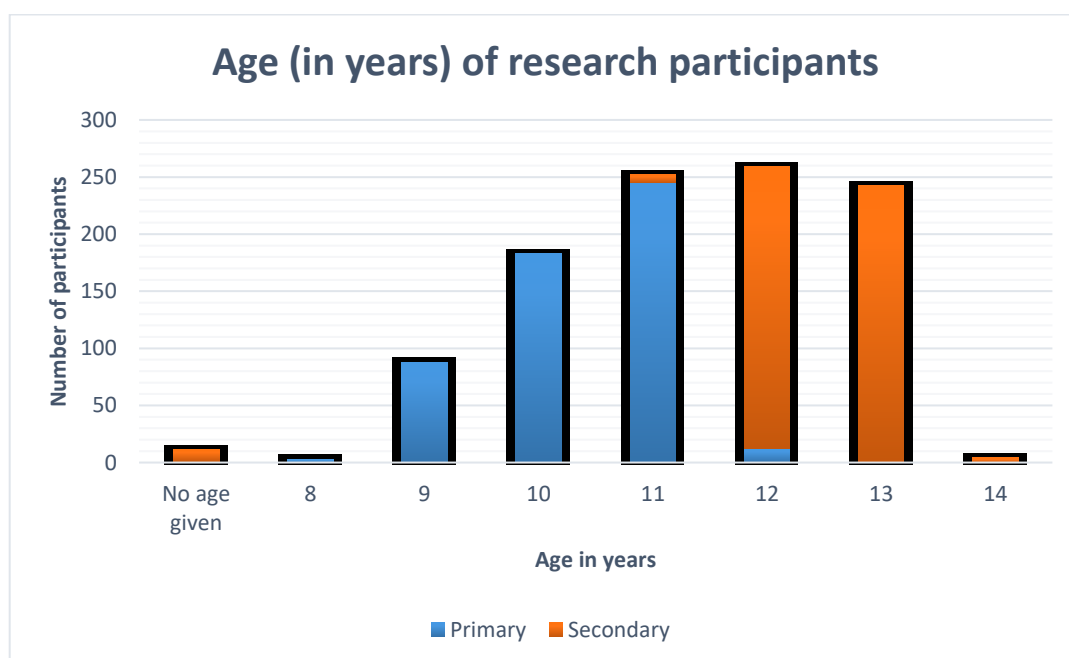


Figure 3.5 Age of research participants

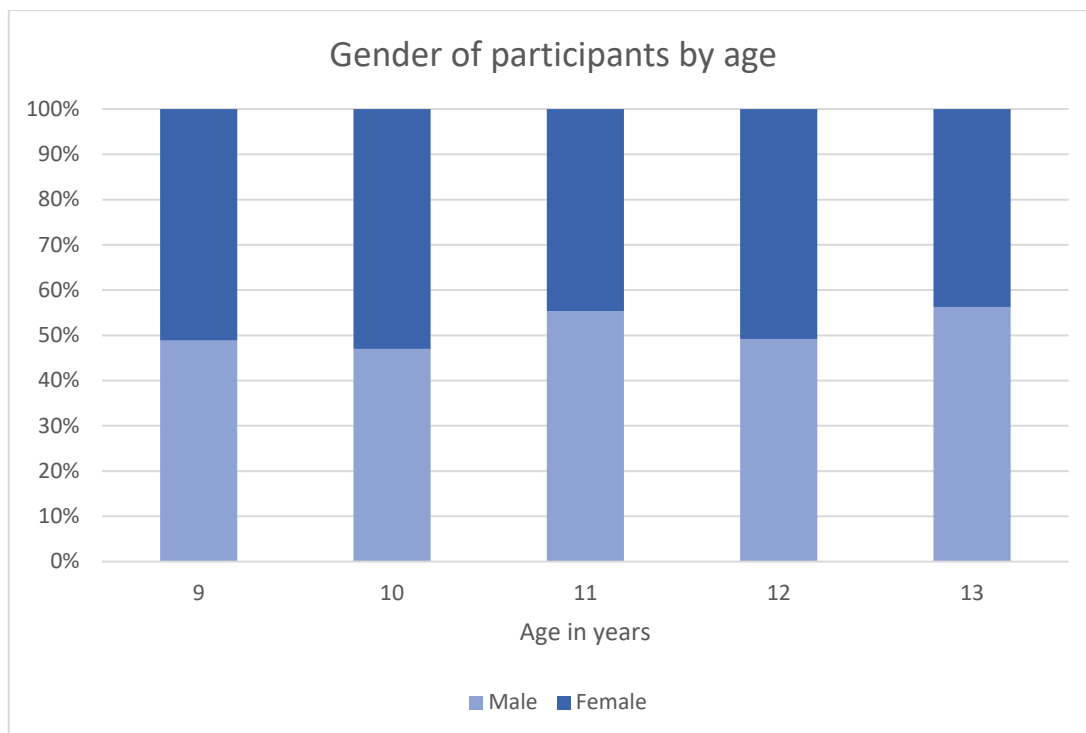


Figure 3.6 Age and gender of research participants

Response rates for the quantitative items within the questionnaire range from 94 – 99%. For the majority of questions and items within questions, differences in the response rates between male and female participants, between participants in primary and secondary schools, and between consecutive age groups (for example, comparing responses from those aged 10 with those aged 9, and so on) are not significant. Items for which differences in response rates by age, gender or sector are significant are shown in Table 3.7.

Table 3.7 Items with significant differences in response rates between different groupings

	% of female participants responding to question	% of male participants responding to question	Significance
How good do you think you are at science?	100 (n = 490)	99 (n = 534)	*
	% of 11-year-olds responding to statement	% of 10-year-olds responding to statement	Significance
My science experience increased my curiosity	97 (n = 244)	92 (n = 169)	*

In response to the question “which of these science things do you enjoy?”, 26 participants selected none of the available options. This is a legitimate response and not considered ‘no response’.

The CRAG participants expected that children would like science more as they got older, particularly once they had experienced science in secondary school. This discussion by the CRAG led to the decision to embark on a second phase of data collection, using the questionnaire with children in secondary schools. The CRAG participants did not analyse and evaluate the data collected from the secondary schools, having themselves made the transition into secondary school during the school year when this data collection took place.

Data Analysis and Evaluation

All data from the questionnaires were entered into statistical analysis software package IBM SPSS statistics (release 22 used with Windows 8 and Windows 10). This included quantitative data in response to questions 1 – 4, and all text entered in response to open-ended questions (questions 5 -7), and the ‘free-response’ space (question 8).

Question completion was also recorded and for the 'free-response' space, an indication of whether text, drawing or both text and drawing had been used in responses. All non-blank, free-response spaces (question 8) were scanned for electronic capture and subsequent analysis. The data from the open-ended questions and free-response space, including all scanned responses, were imported into qualitative data analysis software package NVivo (version 11 with Windows 10).

Using SPSS and NVivo enabled several statistical and qualitative analyses to be performed.

Analysis of quantitative data

Parametric and non-parametric tests

The data were analysed using both parametric (Pearson product-moment correlation, principal component analysis, t-tests) and non-parametric tests (Spearman's rank order correlation coefficient, analysis of frequencies). Analysis of frequencies and bivariate analysis via cross tabulation of nominal and ordinal variables in SPSS (IBM SPSS Statistics v22) were used to explore sample characteristics and responses to closed questions 1 – 4 (Appendix 11), with the percentage of participants selecting responses calculated within SPSS. The data for the 429 research participants in phase I of data collection were used as the basis for data visualisations created using Infogram (2014) software, for analysis and evaluation with the CRAG (Appendices 21-24). For this data-collection phase, statistical significance was calculated within SPSS. For phase II, it became of interest to also explore comparison of percentages. Comparison of percentages was completed using a one or two-sample t-test, or 'N-1' Chi-squared test (Campbell, 2007; Richardson, 2011) as appropriate, using StatPac (2017) and MedCalc (2017, 2018) software.

Correlations

A Pearson product-moment was run to determine correlations between perception of being good at science in school and other participant responses to quantitative questions (Appendix 20). A two-tailed significance test was used because the direction of the relationship could not be predicted (Field, 2000). For the sample size and hence

degrees of freedom of > 1000 , with p-values of < 0.001 , the critical value for the Pearson correlation was taken to be 0.081 (Statistics Solutions, 2017). Each of the correlations tabulated was highly significant, with p-values of less than 0.001 (Table 3.8).

The Pearson's product-moment is a parametric test. It is based on and sensitive to a number of assumptions (Kowalski, 1972), albeit there is a wide range of interpretation about how sample size affects the reliability and robustness of Pearson's product-moment. Recognising that the results for Pearson's product-moment can be misleading where the assumptions are unreasonable (Pallant, 2010), Spearman's rank-order correlation coefficient (ρ) was also calculated. Spearman's ρ is a non-parametric test which is less sensitive to assumptions about distribution and normality; it is the appropriate test for non-parametric data where the data are not at the interval level (Field, 2000). The correlations using Spearman's ρ are shown in Table 3.9. Correlations were strongest between a perception of being good at science and liking learning science in school, as might be anticipated by the work of Haladyna, Olsen, and Shaughnessy (1982) and Schunk (1991), and between the perception of being good at science, and finding science experiences interesting, helpful for learning and contextualised. Based on this analysis, correlations within this thesis were calculated using Spearman's ρ .

Table 3.8 Correlation between perception of being good at science and other responses from participants (Pearson product-moment)

Correlation between perception of being good at science and other responses	Pearson's correlation co-efficient (r-value)	significance
Liking learning science in school	0.423	***
Enjoys a greater number of 'science things'	0.259	***
My science experience was interesting	0.257	***
My science experience made it easy for me to learn	0.256	***
My science experience increased my curiosity about things	0.250	***
My science experience increased my understanding of the world around me	0.239	***
My science experience encouraged me to be creative	0.226	***
My science experience helped me think about environmental, technological and scientific issues	0.213	***
My science experience made me think about jobs	0.199	***
My science experience was fun	0.196	***
My science experience gave me a chance to use modern technologies	0.189	***
My science experience involved exploring new things	0.185	***
My science experience has shown me how science affects our way of living	0.176	***
Enjoys reading science magazines	0.175	***
Enjoys watching science TV programmes	0.156	***
Enjoys doing experiments with science kits	0.137	***
Enjoys visiting places to do with science	0.126	***
My science experience made me think	0.120	***
My science experience helped me to understand Scotland and its place in the world	0.116	***
Enjoys nature walks	0.103	***

Table 3.9 Correlation between perception of being good at science and other responses from participants (Spearman's rho)

Correlation between perception of being good at science and other responses	Spearman's rho	significance	Difference in ranking compared with r
Liking learning science in school	0.428	***	None
My science experience was interesting	0.252	***	-1
Enjoys a greater number of 'science things'	0.245	***	+1
My science experience made it easy for me to learn	0.244	***	None
My science experience increased my curiosity about things	0.242	***	None
My science experience increased my understanding of the world around me	0.239	***	None
My science experience helped me think about environmental, technological and scientific issues	0.220	***	+1
My science experience encouraged me to be creative	0.216	***	-1
My science experience was fun	0.205	***	+1
My science experience made me think about jobs	0.201	***	-1
My science experience has shown me how science affects our way of living	0.186	***	+2
My science experience gave me a chance to use modern technologies	0.186	***	-1
Enjoys reading science magazines	0.179	***	+1
My science experience involved exploring new things	0.175	***	-2
Enjoys watching science TV programmes	0.160	***	None
Enjoys doing experiments with science kits	0.134	***	None
Enjoys visiting places to do with science	0.124	***	+1
My science experience made me think	0.117	***	-1
My science experience helped me to understand Scotland and its place in the world	0.115	***	None
Enjoys nature walks	0.102	***	None

Principal component analysis (PCA)

The sources referred to in carrying out principal component analysis were: Costello and Osborne (2005); Field (2005a, 2005b); Muijs (2010); Neill (2008); Pallant (2010). An example of the use of PCA is discussed in detail in this section.

The 13 statements within question 4 (Figure 3.7) were examined using PCA in SPSS.

4. What would you say about your science experience or experiences? We're asking about experiences outside your normal lessons.

TICK ONE BOX ON EACH LINE

My experience... Yes Not sure No

...was interesting	☐	☐	☐	
...was fun	☐	☐	☐	
...made it easy for me to learn	☐	☐	☐	
...made me think	☐	☐	☐	
...increased my curiosity about things	☐	☐	☐	
...increased my understanding of the world around me	☐	☐	☐	
...has shown me how science affects our way of living	☐	☐	☐	
...helped me to understand Scotland and its place in the world	☐	☐	☐	
...helped me think about environmental, technological and scientific issues	☐	☐	☐	
...made me think about jobs	☐	☐	☐	
...encouraged me to be creative	☐	☐	☐	
...involved exploring new things	☐	☐	☐	
...gave me a chance to use modern technologies	☐	☐	☐	

Please leave blank

© LBoath 2018

Figure 3.7 Question 4 from final questionnaire

PCA is used to attempt to identify any groupings among intercorrelations within data sets (Pallant, 2010). To explore the factor structure underlying these 'perception' variables, PCA is a more appropriate approach than factor analysis for summarising the data set as it provides analysis of all variance rather than only common variance (Tabachnick & Fidell, 2007). An assumption of normality in the data is necessary only when there is an intention to generalise results (Field, 2005b). This was not the

intention in my research study so there was no necessity to establish normality. However, it is noted that PCA assumes that there are no outliers in the data.

Running a correlation matrix in SPSS identified that all of the statements correlated at 0.3 or more with at least one other statement, suggesting that it was reasonable to progress with exploratory factor analysis (Neill, 2008). Bartlett's test of sphericity ($\chi^2(78) = 2781.76, p = .000$) also indicated this as a reasonable way to proceed (Neill, 2008). The correlations and significances did not indicate an issue with singularity within the data and the determinant was above the required value of 0.0001 hence multicollinearity was not an issue for this data (Field, 2005a). The Kaiser-Meyer-Olkin measure of sampling adequacy, calculated by SPSS as 0.902, was above the suggested minimum of 0.5 (Kaiser, 1974 in Field, 2005a) and in a range described as "marvellous" (Kaiser, 1974 in Hutcheson & Sofroniou, 1999, p. 235), although it is recognised that the values suggested by Kaiser were based on smaller samples (Hutcheson & Sofroniou, 1999). With one exception, the communalities were all above 0.3 (Table 3.10).

Table 3.10 PCA on question 4 responses

	Initial	Extraction
Experience was interesting	1.000	.670
Experience was fun	1.000	.636
Experience made it easy to learn	1.000	.393
Experience made him/her think	1.000	.318
Experience increased his/her curiosity	1.000	.428
Experience increased his/her understanding of world around him/her	1.000	.450
Experience showed him/her how science affects our way of living	1.000	.419
Experience helped to understand Scotland & its place in world	1.000	.458
Experience helped to think about environmental, technological and scientific issues	1.000	.444
Experience made him/her think about jobs	1.000	.400
Experience encouraged to be creative	1.000	.405
Experience encouraged to explore new things	1.000	.362
Experience gave him/her chance to use modern technologies	1.000	.283

The diagonal elements of the anti-image correlation matrix ranged from 0.852 to 0.937, comfortably above the absolute minimum of 0.5 suggested by Field (2005b), indicating

that no statements need be removed. I did not, therefore, remove any of the statements before performing the analysis. I concluded that I had sufficient data within the sample to progress with PCA.

The PCA was run several times, in the first instance with eigenvalues > 1.0 and suppressing values < 0.3 (Figure 3.8), in accordance with guidance for a sample size greater than 350 (Tabachnick & Fidell, 2001). Two factors were identified, accounting for 44% of the total variation (Table 3.11).

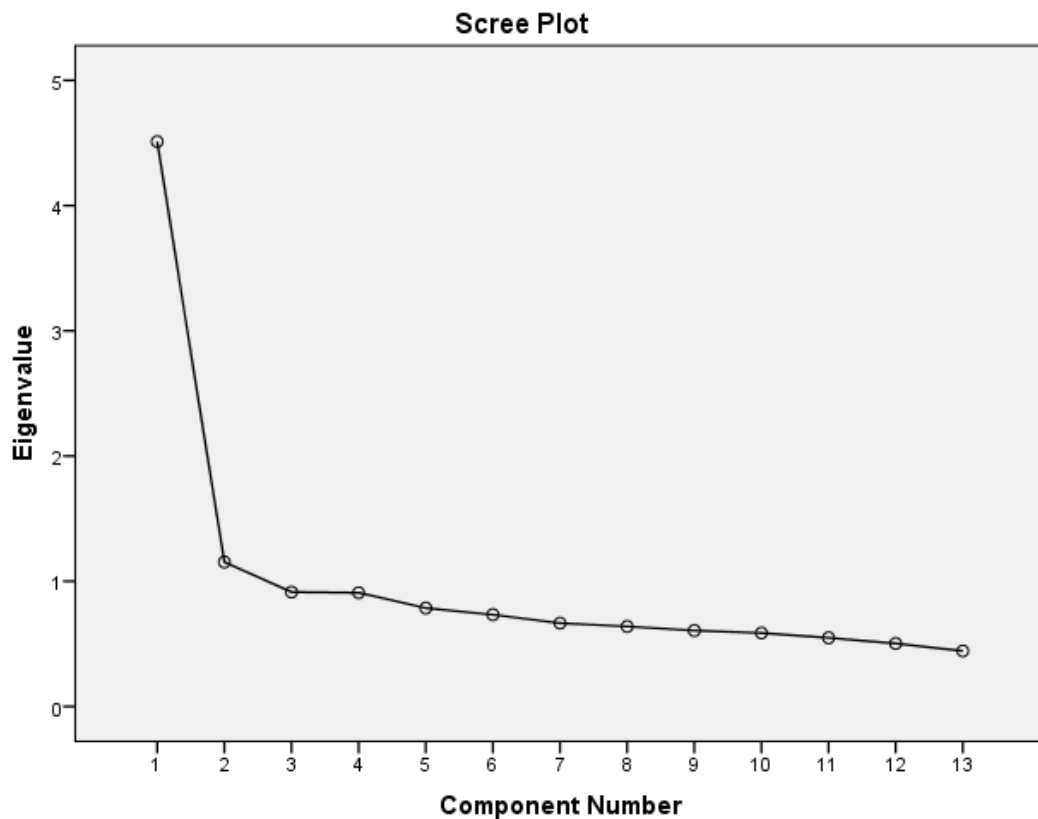


Figure 3.8 PCA scree plot on question 4 responses (eigenvalues > 1.0 , values < 0.3 suppressed)

Direct oblimin rotation was applied; oblique rotation is appropriate because of the belief that the factors should be related to one another (Field, 2005a).

Table 3.11 PCA on question 4 responses (eigenvalues > 1.0, values < 0.3 suppressed):

total variance explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings ^a
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total
1	4.511	34.699	34.699	4.511	34.699	34.699	3.740
2	1.154	8.874	43.573	1.154	8.874	43.573	3.464
3	.914	7.030	50.603				
4	.909	6.990	57.593				
5	.786	6.047	63.641				
6	.733	5.638	69.279				
7	.666	5.120	74.399				
8	.639	4.918	79.317				
9	.607	4.666	83.982				
10	.587	4.516	88.499				
11	.549	4.220	92.719				
12	.503	3.871	96.590				
13	.443	3.410	100.000				
a. When components are correlated, sums of squared loadings cannot be added to obtain a total variance							

There are two items which cross-load at > 0.3 (Table 3.12). This means there are two items, or complex variables, which load at 0.32 or higher on two or more factors (Costello & Osborne, 2005). Costello and Osborne (2005) suggest that complex variables can be removed where they make the interpretation difficult, or they can be retained based on the assumption that the reason for cross-loading is the latent nature of the variable. In this example, each could be considered as relating to both factors, and hence retained. However, Neill (2008) proposes that loadings < 0.5 should be considered 'weak', and Field (2005b) who proposes < 0.4 as 'weak'. By these definitions, the loadings of these items on each factor was weak.

Table 3.12 Factor loadings (pattern matrix) based on PCA with oblimin rotation for 13 items within question 4 (eigenvalues > 1.0, suppress values < 0.3)

	Component	
	1	2
Experience helped to understand Scotland & its place in world	.735	
Experience made him/her think about jobs	.680	
Experience helped to think about environmental, technological and scientific issues	.628	
Experience showed him/her how science affects our way of living	.551	
Experience gave him/her chance to use modern technologies	.528	
Experience increased his/her understanding of world around him/her	.520	
Experience encouraged to be creative	.442	
Experience encouraged to explore new things	.357	-.348
Experience made him/her think	.332	-.320
Experience was interesting		-.868
Experience was fun		-.837
Experience increased his/her curiosity		-.520
Experience made it easy to learn		-.515
a. Rotation converged in 10 iterations.		

Consistency was examined using Cronbach's alpha. The alphas were moderate: 0.782 the first factor (9 items); 0.741 for the second. Excluding items reduced the Cronbach's alpha for each factor. However, I decided to remove the complex variables based on the weak loading of each factor by rerunning the PCA and suppressing loading of < 0.5 (Neill, 2008). This reduced to alpha values, giving alphas of 0.706 for the first factor (6 items) and 0.700 for the second (4 items) (Table 3.13). There are a range of interpretations of appropriate values for Cronbach's alpha (see, for example, Field, 2005b), with values above 0.7 considered acceptable (Field, 2005b, p. 668).

Table 3.13 Factor loadings (pattern matrix) based on PCA with oblimin rotation for 13 statements within question 4 (eigenvalues > 1.0, suppress values < 0.5)

	Component	
	1	2
Experience helped to understand Scotland & its place in world	.735	
Experience made him/her think about jobs	.680	
Experience helped to think about environmental, technological and scientific issues	.628	
Experience showed him/her how science affects our way of living	.551	
Experience gave him/her chance to use modern technologies	.528	
Experience increased his/her understanding of world around him/her	.520	
Experience encouraged to be creative		
Experience encouraged to explore new things		
Experience made him/her think		
Experience was interesting		-.868
Experience was fun		-.837
Experience increased his/her curiosity		-.520
Experience made it easy to learn		-.515
a. Rotation converged in 10 iterations.		

The scree plot (Figure 3.9) shows the point of inflection at two components. However, a point of inflection could also be identified at four components (highlighted in red in Figure 3.9). Whilst inclusion of eigenvalues > 1.0 (Kaiser, 1960 in Field, 2005b) is the norm for a sample size of > 30, there are also some other restrictions on the sample which would make it legitimate to identify components from the inflection point on the scree plot (Field, 2005b). For a sample of greater than 200 participants the scree plot is a fairly reliable approach to identifying number of factors (Stevens, 1992 in Field, 2005b). There is also some challenge to Kaiser's method of using eigenvalues of > 1.0, with a value of > 0.7 proposed (Jolliffe, 1972, 1986, in Field, 2005b). I therefore explored solutions forcing between three and six factors and using orthogonal rotations in addition to oblique rotations. However, in each case, this reduced loading on each factor, increased cross-loading, and decreased Cronbach's alpha values. The PCA was therefore run with eigenvalues of > 1.0, suppressing values < 0.5 to arrive at the two factors discussed in chapter five of this thesis (Table 13).

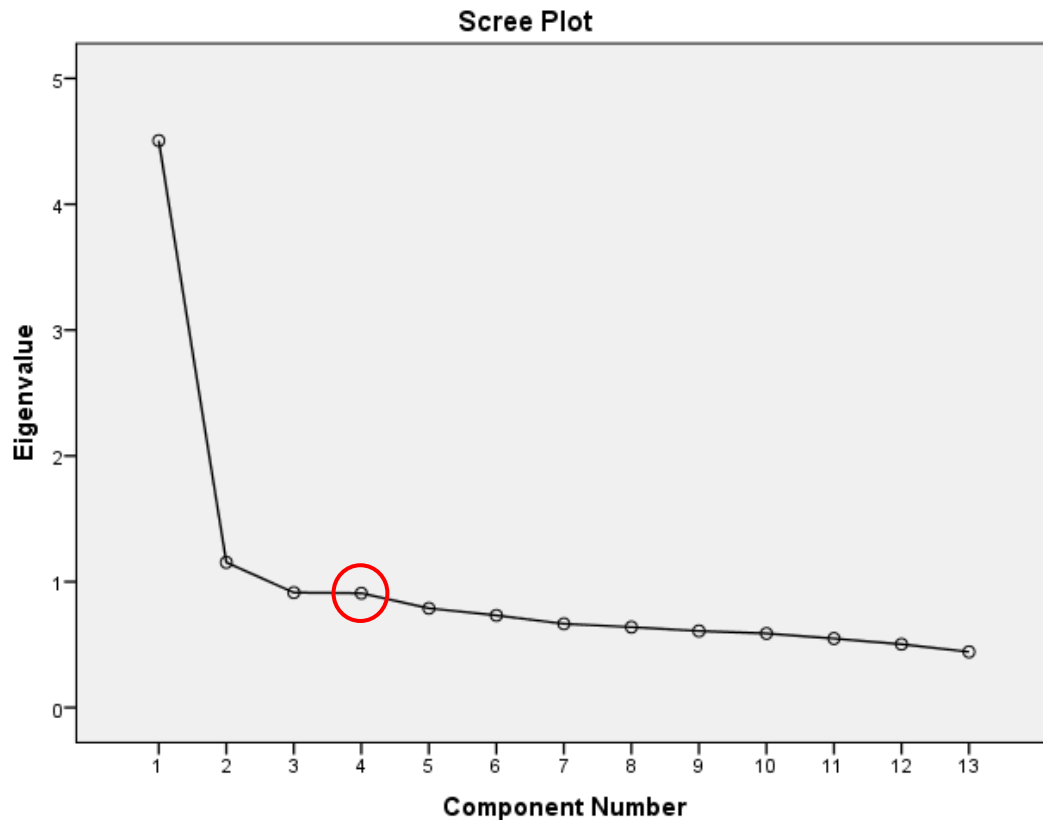


Figure 3.9 PCA scree plot on question 4 responses (eigenvalues > 1.0, values < 0.5 suppressed)

CRAG participants' role in analysis

Meetings 6 to 9 of the CRAG included opportunities for discussions about the research including data analysis and evaluation, using responses from 429 participants in primary schools. Data visualisations (Appendices 21-24) were used to support CRAG participants' exploration of the data.

Analysis of responses to open-ended questions

Phase I Data from participants (n = 429) in primary schools

In the first instance, I reflected upon the data as I transferred them manually into SPSS from the 429 fully or partially completed questionnaires from phase I of data collection with participants in primary schools. I examined all responses to each of questions 5 – 7, using Microsoft Excel (2013) to manually tally appearance of words. These were then gathered into sub-themes and overarching themes. For example, “more electricity”,

“learn about space” and “more chemicals” were initially recorded as ‘physics topics’ and ‘chemistry topics’ and then tallied under the overarching theme of ‘subject specific content’. Similarly, for question 5 “happy” or “happiness” were tallied, and then included in the theme of ‘positive feelings about science experiences’. In this way, I began to see main themes emerging from the responses to open-ended questions. This exercise was carried out with a partner, to ensure that I did not overlook or misclassify any of the responses. The data from this manual exercise were used as the basis for the data visualisations shared with the CRAG participants in meetings 6 – 9, which were created using Infogram software (Appendices 21-24).

Responses to questions 5, 6 and 7 were transferred into a Microsoft Word document with between 5 and 6 responses per A4 page and in a 24-point font size to make them easily readable. The page was guillotined such that each strip contained a single response to the question. These were used to review the responses and sort into themes, to see whether different themes emerged from those identified when inputting the data and when using Microsoft Excel as a tool for analysis. A sample of the question 5 statements were used for the discussion in which CRAG participants identified themes emerging from the responses (CRAG meeting 8). Question 6 statements were also reviewed and sorted in this way by a research colleague. Discussing responses to question 6 with this colleague, we considered using the seven principles of curriculum design underpinning CfE (SG, 2008) as a thematic framework for coding, rather than simply looking for themes emerging from the data.

Where the response to question 8 was not blank, the scanned image of the relevant page from the questions was printed as an A5 colour sheet. These were reviewed by the CRAG to identify themes emerging from the responses.

Within the discussions of responses to open-ended questions, the CRAG made a number of suggestions regarding grouping the themes together. These suggestions influenced how I approached the analysis of the full data set and ultimately what has emerged as the *Findings and Discussion* chapters of this thesis. In the discussions, CRAG participants were identifying how ‘children like them’ might use the words and what

they meant, as illustrated in the transcript extract below, which is from discussions between a group of three girls (AG, BG and FG)¹¹ and one boy (KB).

CRAG (AG): So, what do you think about these graphs and ideas?

CRAG (BG): Good and enjoyed should be together

CRAG (AG): What good and enjoyed?

CRAG (KB): Yeah that's...

CRAG (AG): You'd think a lot more people would think it was exciting.

...

CRAG (KB): Why are awestruck / awesome / stunned together?

[discussion]

CRAG (AG): Awesome and cool should be together.

CRAG (KB): Yep awesome and cool, then awestruck and stunned should be together.

CRAG (AG): Yep.

CRAG (KB): Yeah. So awesome and cool

...

CRAG (AG): There's more to science than meets the eye!

CRAG (AG): So, guys, what do you think about science? [laughs]

CRAG (BG): Okay, so we've decided to put 'fun' and 'happy' together, and 'creative' on its own...

CRAG (AG): no, that's just what we chose. And then, we decided to put 'awesome' and 'cool' together and 'awestruck' and 'stunned' together.

CRAG (BG): Awestruck, means they're like stunned and like shocked.

CRAG (BG): We put 'good' and 'enjoyed' together.

Researcher: Okay, so note all that down, because what I can do is redo the analysis of how you think it should be done and see if that gives us something...something different, so that's great.

The transcript extracts included in Appendix 25 also illustrate the CRAG participants' discussions as they review the questionnaire responses and explore their wider understanding around the issues being researched.

¹¹ Girl FG contributed throughout discussions and I was unable to separate her voice from AG and BG, hence some of the remarks attributed to AG and BG must have been made by FG.

The final stage in the CRAG participants' analysis was to discuss the full statements written by the research participants. For this discussion only seven CRAG participants were present. Twenty of the research participants' responses to question 5 'feel' were transferred to slips of paper as illustrated in Figure 3.10. The CRAG participants initially looked at some of the statements which they chose at random. They then suggested that they should divide them up roughly equally and take turns reading the statements aloud to see if there were any patterns or groupings evident (Emerson, Orr, et al., 2014). As they read the statements, the CRAG participants queried anything about which they were unsure. It was clarified that the statements were exactly as participants had written them.

I feel amazed about all the sciency things, it also makes you think more clearly and I loved learning more. Hope to learn more in the future.	Qu5feel
It makes me excited, it makes me feel smarter and I think will help me grow up, science is a great thing and everyone should take part. Science can help the world and help people make technology, science we need it to survive.	Qu5feel

Figure 3.10 Example of participants' responses transferred to individual slips of paper for CRAG participants' consideration

The CRAG participants began to identify themes as they read the statements aloud to the group. At the same time, they began discussing the process in which they were engaged, of identifying themes from data as researchers do. As some began to suggest emerging themes, others then identified statements to read which they felt fitted with these. There was discussion around how to capture the themes in words, and debate about whether statements fitted with particular themes. CRAG participants also identified and discussed complexities of statements fitting into several potential themes, and of trying not to put their own interpretation on statements to make them fit potential themes. Using this process, CRAG participants identified themes as 'want to do more', 'confidence', 'people's futures', 'being excited', 'feeling smarter' and 'stuff about the world'. These are reflected in the *Findings and Discussion* chapters.

Working with a student colleague

The first four meetings of the CRAG were attended by a former pupil, whom I taught for two years as she studied for qualifications in physics at school. Her involvement offered inter-observer reliability. Together, we discussed the interactions and activities, our observations and emerging thinking, while CRAG participants were working on activities, during breaks, and between meetings. She also participated in review of iterations of the questionnaires, in particular the extent to which it reflected the thinking and ideas of the CRAG participants.

Phase II Data from participants (n = 614) in secondary schools and additional primary schools

Data from the additional 614 participants were entered manually into SPSS. The same manual exercise undertaken in Phase I, tallying appearance of words in Microsoft Excel, was carried out with a partner, to identify themes emerging.

Coding data in NVivo 11 and inter-rater reliability

The data from all research participants (n = 1043) were exported from SPSS to NVivo (QSR International, v11). For questions 5 – 7 I coded manually in NVivo, each time doing several iterations including re-examining those coded to particular themes and those excluded. I then identified emerging themes, as discussed in the *Findings and Discussion* chapters. I used the NVivo word search query to identify most frequently appearing words in the responses to each question, examining the responses to contextualise these words. This process further informed my thinking around emerging themes. The NVivo word cloud function provided a visualisation of the words included in responses by frequency, and then within coded theme by frequency. As themes began to emerge, the NVivo text search function allowed me to identify responses with stemmed words and synonyms of key words relating to the theme, and through this to consider inclusion or exclusion of those responses.

Question 7 What can science experiences do to help you enjoy science more?

Once this exercise had been completed for question 7 “what can science experiences do to help you enjoy science more?”, two main themes emerged. The first was ‘interactivity’, a desire for active involvement rather than passive attendance. The

second was that science experiences should matter, with challenge and purpose, and should be about more than entertainment, frivolity and novelty. Having focused on these and completed further iterations of the coding, I shared all the responses to question 7 with a colleague from the School of Education & Social Work at the University of Dundee. My colleague identified all responses which could be coded as 'interactivity', with high levels of agreement. We then explored those on which there was not agreement; this exploration involved discussion with three other colleagues. The debate focused around responses referring to "experiments" and "games". The same approach was used with another colleague, exploring the theme that science experiences matter more than entertainment. Additionally, within the theme of 'interactivity' there emerged an element of social or human interaction. The process was therefore repeated in full, with a third colleague, to identify phrases which could be coded to a theme of 'beyond the individual'.

Colleagues coding the responses each identified 'technologies' and 'games' as emerging themes. Each of these was explored further (see *Findings and Discussion* chapter five). Throughout, this process was used to focus in on areas of disagreement and through this to challenge the interpretation and robustness of the coding. Cohen's kappa coefficient was not calculated because of the considerable limitations of using Cohen's kappa coefficient (Gwet, 2014; Wongpakaran, Wongpakaran, Wedding, & Gwet, 2013).

Question 6 What can science experiences do to help you learn?

The methodology and use of NVivo for question 6 was the same as question 7. It became apparent that broadly similar themes were emerging from the participants' responses. The same colleagues coded question 6 responses for the themes of 'interactivity', 'more than entertainment' and 'social element'.

Question 5 How do science experiences make you feel about science?

The coding of this question was informed by the input from the CRAG (meeting 8). As each response was reviewed, key words and phrases relating to feeling were coded, such as "happy" and "more confident" quite specifically, for example to a theme of 'happy or happiness', 'increased confidence'. Words appearing frequently were identified and phrases coded. For example, "experiments" appeared frequently, so phrases containing this were reviewed for coding to indicate a mention of experiments. They were coded to again if there was reference to experiences and a positive feeling

associated with experiments. This process was repeated four times, comparing and aligning with the CRAG's discussion on themes emerging from the sample of question 5 responses. After coding items 6 and 7, I then explored question 5 to identify whether the themes of 'interactivity', 'science experiences should matter' and 'beyond the individual' emerged from question 5 responses.

Levels of agreement through inter-rater reliability

All responses to questions 6 and 7 were shared with a colleague who independently coded responses fitting within the theme of 'interactivity'. We then compared areas of disagreement. On the first pass there were 196 statements on which there was not agreement, of 806 non-blank responses to this question, giving 76% agreement on the first review. The major source of disagreement was around the inclusion of statements relating to a wish to visit more science experiences and go on more trips, for example,

“be outside more”

(participant, age 13, secondary school).

After further discussion, responses such as these were excluded. The purpose of the questions was to explore how science experiences can help children enjoy science more and learn through science experiences, rather than whether they want to visit science experiences and have school trips. Those indicating a level of participation or active engagement were included, for example,

“I think that science experiences could help me if there was...more things to explore”

(participant, age 10, primary school).

The final level of agreement on this question was 100%. Responses to question 6 were shared with the same colleague who independently coded the phrases fitting within the theme of 'interactivity'. On the first pass there were 83 statements on which there was not agreement, of 832 not blank responses to this question, giving 90% agreement. There is greater agreement about coding the responses to question 6 than question 7 on the first pass. We completed the question 7 coding first, and during that process

had discussed and explored areas of disagreement, making the coding of question 6 more straightforward. The final agreement on question 6 was 100% (n = 369).

I coded for the second theme, that science experiences should 'matter'; a colleague also coded independently. For question 7, on the first pass there was 91% agreement with 70 statements on which there was not agreement. After further discussion around our thinking on the emerging theme, we each coded these again. On this second pass there was 98% agreement with 15 statements on which there was not agreement. On the final coding, following a third review, there was 96% agreement with 31 statements on which there was not agreement. Disputed statements included those in which the participants requested opportunities to research and have questions answered, for example:

"getting to do research on stuff we didn't know existed"

(participant, age 10, primary school);

"if it is fun and we do our own experiments, and have people to answer our questions"

(participant, age 13, secondary school).

In the coding of question 7, I included more responses than my colleague. However, when we carried out the same coding exercise for question 6, with 76% agreement on the first pass, my colleague included more responses than I identified. My colleague included 161 which I excluded and omitted 38 responses which I had included. My colleague's coding included statements which did not extend beyond answering the question "what can science experiences do to help you learn?" for example:

"I think science games and science computer games would help me learn"

(participant 7, age 11, primary school);

"I learn best when I can touch and hear the things, and when I do experiments and doing treasure hunts all help me to learn"

(participant 7, age 11, primary school).

Excluding such statements, there remained 56 statements which were included by my colleague but which I excluded, and 38 statements which I coded which were excluded by my colleague, giving 89% agreement on this question. After a further round of coding, the 258 statements were identified which both reviewers agreed should be coded to a refined category of 'it matters: challenge and purpose'.

For question 7, exploring the theme of 'beyond the individual' on first coding in NVivo, I identified 100 responses and my colleague identified 96. After a second pass, 112 responses had been identified with three statements still the subject of disagreement. Coding question 6 in the same way, on the first pass, I coded 128 phrases and my colleague 111. On second pass, discussing areas of disagreement, we reached 100% agreement on 113 responses.

Using NVivo 11 tools and Microsoft Excel

Once coding had been completed, the word count frequency tool in NVivo was used to create tables of data which were exported to Microsoft Excel to examine the overlap of phrases containing different key words, and themes across different questions. The NVivo matrix coding query, and NVivo visualisations to aid exploration and comparison of query outputs were also used to inform this analysis.

Word count using SPSS and Microsoft Excel

Responses to questions 5-7 from all participants (n = 1043) were exported from SPSS into Microsoft Excel. A spell check was run for obvious typographical errors, such as the word "expermients", and words where meaning was clear such as the word "interessting". Changes were not made where the meaning was unclear, such as in the responses "It's a foceing subject, it's interessting but I not a fan at science" (participant, age 11, primary school) or "more opsinses" (participant, age 9, primary school).

All punctuation was removed from the responses, using Visual Basic coding, before apostrophes were re-inserted using the spell check function and manual checking. A function of Microsoft Excel was then used to count the number of words per response. Spaces were removed, and a function of Microsoft Excel used to count the number of characters per response. These were totalled using a function of the software.

Calculations were carried out

- mean word length = total number of characters / total number of words
- mean number of words per response = total number of words / total number of responses
- mean number of characters per response = total number of characters / total number of responses.

Bringing together quantitative and qualitative data: identifying themes

The various approaches to familiarising myself with the data, and to exploring the data to identify emerging themes including with the CRAG participants, also provided opportunity to develop my thinking on how the quantitative data and data from the open-ended questions might come together. In the main, the quantitative data report on perceptions of learning science and science experiences as they are, whilst the open-ended question responses provide a picture of children's thinking on what they could or should be. Within findings and discussion, I have therefore identified the narrative emerging from the open-ended questions and from this, explored the quantitative data to enrich, enhance or challenge this.

Chapter 4 Findings and Discussion: learner at the centre

In Scotland, there is a focus on placing the learner at the centre of learning and teaching (SG, 2008). However, there remains a question mark over the extent to which this is anything more than tokenistic (see, for example, Sher et al., 2010c; Tisdall, 2007, 2013). In this chapter I examine the children's rights-based methodology as a mechanism for placing children at the centre of research, in the context of CHT.

Creating ZPDs for CRAG participants

Early experiences and first steps

While Vygotsky focused his exploration of the ZPD on formal educational settings (Wertsch, 1985a), I propose that the children's rights-based methodology employed within my research is an enactment of CHT, the use of which can create ZPDs in contexts other than formal educational settings. My study provided an opportunity for working with children as coresearchers over a prolonged period of more than two years. At the beginning of the process, participants were in primary 5, aged 8-9. They continued to participate in the CRAG until the end of primary 7, when they were aged 11-12 and making the transition to secondary school. The prolonged engagement of children with this research study is unusual; the time required to build rapport with children and to reduce power imbalances by building trusting relationships with children is potentially a limitation of involving children in research, constrained, as it often is, by funding and time (Spyrou, 2011).

The challenge in developing informed voice is to create a ZPD, a "special form of interaction in which the action of the adult is aimed at generating and supporting the child's initiative" (Zuckerman, 2007, p. 43). Key to this is the "equal but different" (Zuckerman, 2007, p. 43) relationship between the adult coresearcher and children participating in the CRAG. One of earliest questions asked by CRAG participants during our first meeting was about how the participants had been identified and chosen. They were concerned that more children had wanted to participate and been included than had initially been intended (see *Children as coresearchers: Children's Research Advisory Group (CRAG)* in chapter three). This indicates the starting point for the CRAG

participants, none of whom had previously been involved in research. In particular, it reveals their perceptions of the imbalance of power in the relationship between them as school pupils and children, and the adults with whom they interact. They were concerned: was it okay for them to want to take part and to express a view which 'disrupts' an adult's plan? At this stage, the CRAG participants did not perceive that the relationship was "equal but different" (Zuckerman, 2007, p. 43) and thus the requirement for it to be so to create a ZPD was not met. Addressing the power imbalance and equality of relationship underpins the children's rights-based methodology employed within the study and so provides for this condition for creation of a ZPD.

There are advantages and disadvantages of forming a CRAG from a full class group as I did in this study. Choosing some children from a class group to participate in a CRAG provides a 'higher role' for those selected. In identifying this higher role, and drawing on their social understanding of how one might behave in such a role (Mesquita, 2012), we create an opportunity for learners to act as though "a head taller" (Vygotsky, 1978, p. 102) thus creating a ZPD (Murphy, 2012). This aspect was not lost when using the whole class group. The children were aware that their class had been chosen out of all classes in the school and that they were representing the school. The children who participated in the CRAG were of an age where 'play' is no longer considered the leading activity for development (Kravtsova, 2006). Nevertheless, Kravtsova (2006) notes Davydov's argument that educational or learning activity as the leading activity for the relevant age group can take "a collectively distributed form that very little resembles education and is much more reminiscent of play" (p. 9). Vygotsky's consideration of play was specific to dramatic or make-believe play, in which children "take on and act out roles, and follow a set of rules determined by these specific roles" (Bodrova, Germeroth, & Leong, 2013). Through CRAG participation, children initially act out roles and follow a set of rules before **becoming** coresearchers, by internalising these rules and inhabiting the role. Egan and Gajdamaschko (2003) describe the process in relation to the self-generation of images when reading literature: "The image can carry the imagination to inhabit in some sense the object of our study and inquiry. By such means mathematics and physics, history and auto mechanics are not conceived as external things that the student learns facts about but become a part of the student; students thus learn that they are mathematical, historical, mechanical creatures" (p. 91).

Through participation in the CRAG and the activities designed to enable participants to access information to inform their voices, the CRAG participants move from seeing the research process as external to them and belonging to the adult coresearcher and begin to **be** coresearchers. Thus, the opportunity to act as though “a head taller” (Vygotsky, 1978, p. 102) is not lost by inviting the whole class to participate in the CRAG. The children’s rights-based methodology need not be exclusive in order to create a ZPD.

The class is a unit, with an established dynamic. This can be positive. The CRAG participants did not need to form new relationships and get to know one another, they had established group interactions and may already have felt ‘psychologically safe’ leading to increased participation (Billson, 1986). Where the class grouping is one in which children have learned to listen to and respect the contributions of their peers, working as a group can generate a wider range of responses than would be obtained working individually, with children extending the ideas of others within the discussion (Lewis, 1992). The positive aspects of the class grouping, and existing relationships were evident when undertaking the concentric circles activity (Appendix 9). The children chose to spread the sheet out on the floor and lie around the sheets like the spokes of a wheel. The decision to do this arose spontaneously, with suggestions from participants: “Wouldn’t it be easier if we...?” and “Why don’t we...?” Together, they reached a consensus on how they could best work together. At this early stage of participation and building of relationships between me and the children, there was still hesitation about the balance of power. The children were still ‘checking in’ with me that their proposals on how to work together were acceptable. Within the ZPD model proposed by Tharp and Gallimore (1988), this can be considered the first stage in which the ‘learner’ looks to the ‘teacher’ for assistance, to develop a shared understanding, in this case of the culture of working together on research (Fani & Ghaemi, 2011).

In the early stages, I modelled the role of the coresearcher and the CRAG participants responded with ‘imitation’ (Wertsch, 1985b). This contrasts with later meetings of the CRAG, as the children progressed from the teacher-assistance stage into self-assistance, where the tasks were “handed over to the learner” (Gallimore & Tharp, 1990, p. 185). There was not the same hesitation, expressed verbally or signalled non-verbally, in deciding as individuals or a group on an appropriate approach to use. In the concentric circles activity, as the children worked while lying on the floor around the sheets of

paper, there was active, relevant discussion. Again, the participants reached consensus on how best to approach the task, deciding to review each other's contributions and tick for agreement, rather than each writing similar statements (Appendix 9). Consequently, they engaged in a process of discussion and debate, articulating, clarifying and challenging thinking as they worked together. Through this peer collaboration, facilitated by the existing relationships between the CRAG participants, social interaction led to CRAG participants achieving what they could not alone (Chaiklin, 2003; Tudge, 1990). In its most simplistic interpretation, this captures the meaning of the ZPD.

There is a risk that any negative aspects within the class group are brought to the CRAG. Within a small group, children take on particular roles which can support or hinder the group working together (Billson, 1986). The class group can be influenced by children with strong views (Lewis, 1992), or by those with the confidence to vocalise views. Within CHT, the individual transformation is emphasised as the precursor to societal transformation (Robbins, 2010); appropriate social interactions must be created for each individual. The ZPD cannot be created without appropriate social interaction. Thus careful planning was necessary, for each of space, voice, audience and influence (Lundy, 2007), and for building and supporting the relationships within the CRAG. Building and managing relationships, the 'peer ecology' of the classroom (Hendrickx, Mainhard, Boor-Klip, Cillessen, & Brekelmans, 2016), is widely recognised as key to pupil motivation, academic achievement and teacher wellbeing (Pennings et al., 2014). It is central to my role as a classroom teacher and as a teacher educator. Although I was careful not to act in the role of 'the teacher' or to be perceived as such by the CRAG participants, my classroom experience was very valuable in managing and supporting the interactions within the CRAG and between the CRAG participants (Hendrickx et al., 2016).

Equally important was the role of a university student colleague, a former pupil of mine studying for a degree in electronic and electrical engineering who participated in CRAG meetings 1 to 4. Her presence provided a bridge, mediating between me and the CRAG participants, disrupting the adult-child dynamic which may otherwise have led to the children behaving as they typically would in the class with their teacher. Her presence also provided a better balance of social powers (Alderman & Green, 2011) in the CRAG

setting, through which trust and respect could develop (Frymier & Houser, 2000). Considering the class as a 'small group' in the sociological sense (Billson, 1986), my student colleague took a role which provided balance between the structure of the CRAG meetings, and meeting the socio-emotional needs of participants. The ZPD relates both to emotional and intellectual processes of development, which are inseparable (Kravtsova, 2009; Levykh, 2008). Supporting the balance between these elements (Levykh, 2008) through the presence of my student colleague was an important factor in creating a ZPD for CRAG participants.

In the first meeting of the CRAG, participants discussed where they had come across questionnaires or surveys. The only example suggested by the children was "in a hotel". When thinking of the 'best science centre ever' (Appendix 9) more than a quarter of 40 responses provided by one sub-group¹² of the CRAG, related to safety, hygiene and facilities, including: "safe and sensible activities"; "sensible equipment"; "nice food at a café"; "not dirty"; "clean"; "tidy toilets"; "clean toilets"; "no germs"; "look clean from the outside and inside". Similar themes emerged from the discussions of 'what should a science centre not do?'. For this activity, the boys and girls were split into two separate groups. This was not for the examination of gender differences but as one of a number of ways in which the full CRAG was split into sub-groups as activities and needs required. It was also used to introduce the idea of gender as a perspective to consider. Responses from girls included: "dirty walls and floors"; "have a bad smell", "out of date food and drinks"; "no café"; and from boys: "(have) no health and safety rules"; "disgusting"; "not have anywhere to rest".

The participants' responses are not data for my research, nor a measured baseline. However, such responses are helpful to consider in reflecting on the CRAG participants' extended involvement with the research project. These early responses indicate that the children's words are only partially theirs (Bakhtin, 1986). Their responses are likely to reflect what they have heard from the adults in their lives, within and beyond school, and they may be saying what they think adults will want to hear (Kuchah & Pinter, 2012). This is an interesting aspect of the process of children's participation in research and

¹² This CRAG meeting, attended by a research colleague from Trinity College Dublin and student colleague, took place at IMSAT. The CRAG was divided into two sub-groups to facilitate visiting laboratories and other facilities within IMSAT. This division was done by selecting badges to randomly pair CRAG participants and then grouping those pairings.

developing informed voice. One of the criticisms of the development of informed views of children as coresearchers is that there is a risk of leading children to pre-determined responses formed by adults. Such criticism fails to recognise the risk inherent in gathering views from any age group; how much of their words are really their own as opposed to reflective of societal norms and expectations? The determination to develop informed voice gives participants an opportunity to express their own views. This contrasts with typical research in which an assumption of informed voice is made, and no support is given to the formation of views through access to information and building the capacity of those participating in the research.

The insight of the CRAG participants in developing the research instrument

In CRAG meeting 4, the CRAG participants tested the research instrument, and critiqued the design (Appendix 14). Focussing on substantive issues within the questionnaire, they made contributions, building on one another's thinking. By this stage in the research process, it was evident that the CRAG participants had moved beyond the first two stages of the ZPD (teacher- and self-assistance) (Gallimore & Tharp, 1990), beyond being imitative (Wertsch, 1985b). Instead their role as coresearchers had been internalised; in this role, they were no longer developing but were developed (Gallimore & Tharp, 1990). Identifying that the layout of question 4 (Figure 4.1) would be confusing for research participants, the CRAG participants suggested amendments which were incorporated in subsequent versions of the questionnaire (Figure 4.2). The CRAG also proposed adding an additional category to question 4 about use of modern technologies within science experiences. They anticipated that access to modern technologies would be something which would emerge from the research participants as something to help them learn or enjoy science experiences more. CRAG participants also proposed that the image labels within the questionnaire should be handwritten by them, and this is reflected in the questionnaire used with research participants (Figure 4.2).

4. What has been your experience of science centres?

My science centre experience...	Yes	Not sure	No
...was interesting	☐	☐	☐
...was fun	☐	☐	☐
...made it easy for me to learn	☐	☐	☐

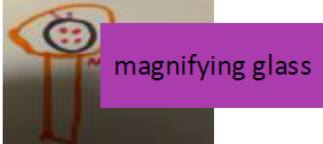


Figure 4.1 Extract (question 4) from questionnaire version 4

4. What has been your experience of science centres?

My science centre experience...	Yes	Not sure	No
...was interesting	☐	☐	☐
...was fun	☐	☐	☐
...made it easy for me to learn	☐	☐	☐



Figure 4.2 Extract (question 4) from questionnaire version 5

The CRAG participants discussed what would be the most appropriate response options for question 4. There was an initial preference for a visual system such as 'smiley faces' instead of using text labels for responses. As they discussed this further, the CRAG participants could not identify a visual system for responses which they felt would be clear, easily understood and have the same meaning as the wording "yes, no, not sure". They felt it would be difficult to develop a visual system which would give clarity about the meaning of research participants' responses. Thus, they agreed "yes, not sure, no" options should remain. Emerging research, published after data collection for this

thesis, suggests that use of smiley faces in addition to text does not slow down processing of questions, and is helpful for respondents with lower literacy levels (Stange, Barry, Smyth, & Olson, 2016). Where responses include both smiley faces and text, respondents spend less time on the question stem, although it is not clear whether this is to do with increased processing speed or less attention to the question (Stange et al., 2016). Other research suggests that the images used can influence responses given, moving them from more moderate to more extreme responses (Reynolds-Keefer & Johnson, 2011). Overall, there is nothing to undermine the view of the CRAG participants that it is more important to have clarity of meaning of responses communicated via text than to have visually friendly response options.

The CRAG participants also proposed that the instructions for completing all questions be clarified and made easier for research participants to see and understand. Figure 4.3 illustrates this change for question 4.

4. What would you say about your science experience or experiences? We're asking about experiences outside your normal lessons.

TICK ONE BOX ON EACH LINE

My experience...	Yes	Not sure	No
...was interesting	☐	☐	☐
...was fun	☐	☐	☐
...made it easy for me to learn	☐	☐	☐

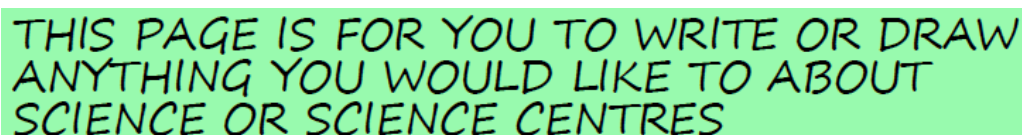


Figure 4.3 Extract (question 4) from questionnaire version 11

This insight from children about what ‘people like them’ (Murphy et al., 2013) would need to be able to understand how to use the questionnaire gives reassurance about the quality of data gathered when working with children as coresearchers. Despite my intention to design a questionnaire appropriate to the age group and developing the early drafts from the CRAG participants’ ideas and thinking, there remained barriers to participation and understanding. It is unlikely that these would have been identified or addressed without children as coresearchers. A feature of the questionnaire overall was the number and amount of different and sometime clashing colours used, as well

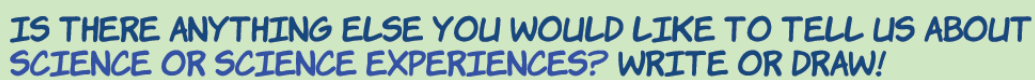
as the variety of fonts. The CRAG felt this was important for children's enjoyment and engagement with the questionnaire. As a result, the questionnaire (Appendix 11) is visually very different from others designed by adults for use with children (see for example, the *ROSE* survey (Schreiner & Sjöberg, 2004)).

The CRAG participants were concerned that the wording for question 8 (Figure 4.4) would confuse research participants and would lead to responses relating to what participants would like to know about science or science centres. They formulated a number of possible statements for discussion before agreeing on the wording shown in Figure 4.5.



THIS PAGE IS FOR YOU TO WRITE OR DRAW
ANYTHING YOU WOULD LIKE TO ABOUT
SCIENCE OR SCIENCE CENTRES

Figure 4.4 Extract (question 8) from questionnaire version 4



IS THERE ANYTHING ELSE YOU WOULD LIKE TO TELL US ABOUT
SCIENCE OR SCIENCE EXPERIENCES? WRITE OR DRAW!

Figure 4.5 Extract (question 8) from questionnaire version 11

The insight of the CRAG participants in data analysis and evaluation

Meetings 6 to 9 of the CRAG, which took place over a four-month period (Appendix 6), included opportunities for discussion about the research findings. Data analysis and evaluation were supported by a variety of data visualisations (Appendices 21-24). The first data shared in CRAG meeting 6 related to the demographics, age, gender and geographical location of participants (Appendix 21). The CRAG participants also reviewed visualisations of whether participants' science experiences had taken place only with school, only with friends or family, or both with school and with friends or family (Appendix 22). As well as familiarising the CRAG participants with the data collected in the first phase, working with straightforward visualisations played a role in building participants' capacity for analysis and evaluation of the questionnaire responses. Having had a period of time between meetings of the CRAG during data collection, recursion through the ZPD was evident (Gallimore & Tharp, 1990) for some

individual participants and therefore for the CRAG as a whole. This fourth stage of the ZPD where “what one formerly could do, one can no longer do” (Gallimore & Tharp, 1990, p. 187) and further assistance is needed is part of a normal development process and the cycle of lifelong learning. Meeting 6 also took us into new development and creation of a new ZPD and thus began with greater adult assistance and modelling of the coresearcher’s role in data analysis and evaluation, to provide opportunity for imitation, moving to self-assistance through to internalisation.

To examine the quantitative data in response to the question “What would you say about your science experience or experiences?” (Appendix 11, question 4) the CRAG was split into three groups¹³, and invited to predict the participants’ responses to each of 13 items. Each group was provided with one of three bar charts: “Yes, my science experience...”; “No, I don’t agree that my science experience...”; “My science experience...I’m not sure that it...” (Figure 4.6). The bar charts were ordered to reflect the responses to this question, and labels were omitted. The groups were given the statements to sort and attach to the bar chart, prompted by the questions “Which ones go together? What do you think children said?” (Figure 4.7).

The groups were provided with the labelled bar charts to compare with their predictions, counting how many they had correctly predicted, reflecting on those which were reasonably close to the results, and identifying those which were different from their predictions. Discussing what had or had not surprised them about the results, they noted anything else they would like to know. The discussion prompts used reflect those employed by Murphy et al. (2010). The groups noted their thinking and discussions using sheets modelled on the questionnaire design, examples of which are shown in Figure 4.8.

¹³ Approaches to grouping or pairing to facilitate more effective working included participants lining up by shoe size to be allocated a group number; grouping the three boys together, before pulling ID badges out of a ‘hat’ to pair the girls. Approaches were used to avoid fixed pairings / groupings, or children pairing up in ways which might lead to some feeling excluded.

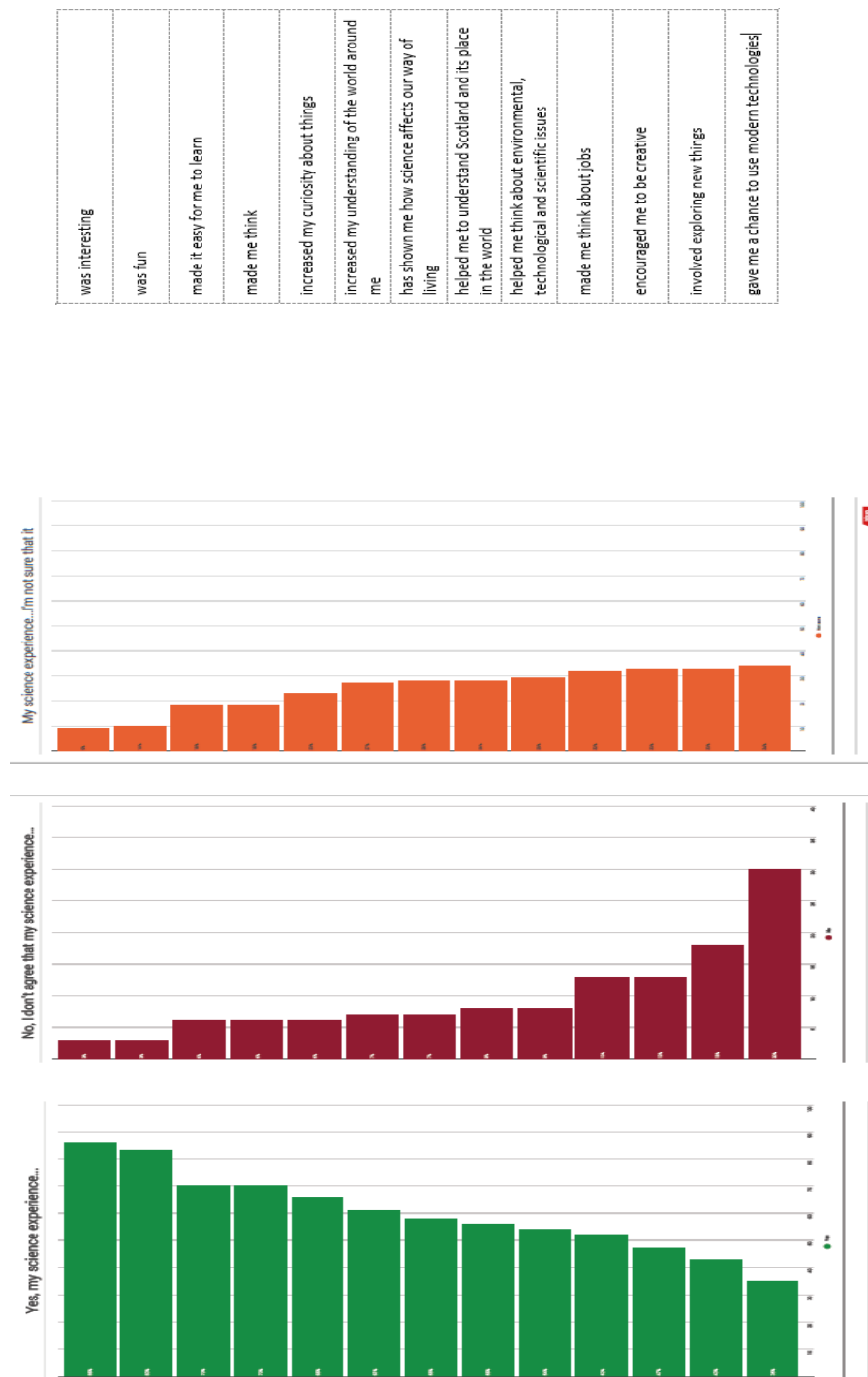


Figure 4.6 Bar charts used by CRAG to discuss responses to question 4 about science experiences

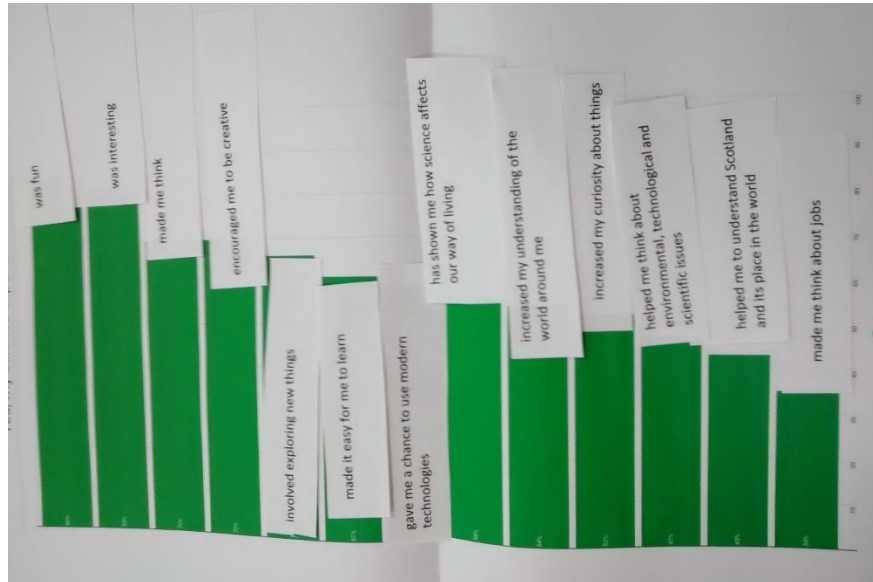
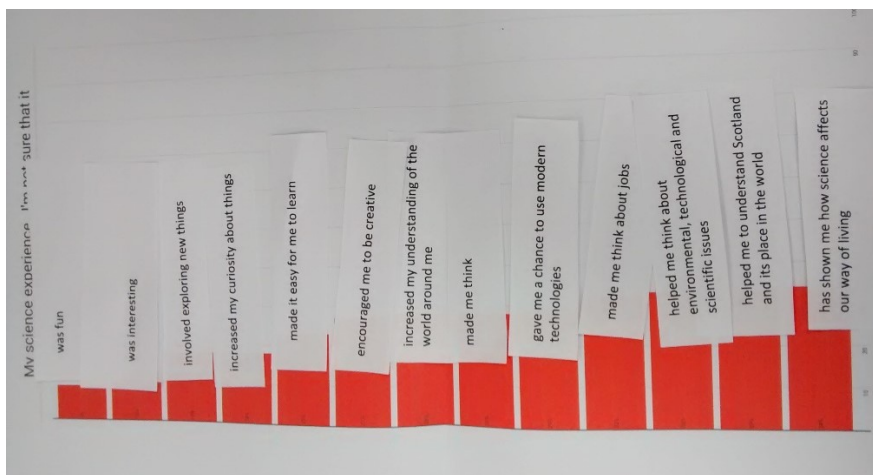
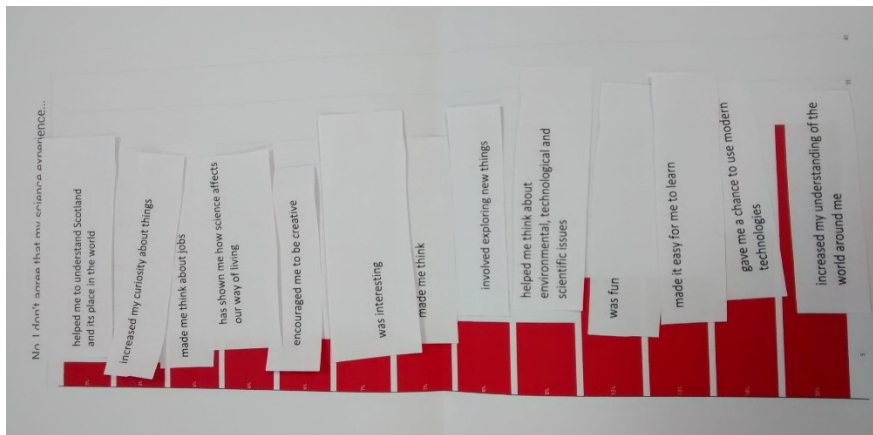


Figure 4.7 Use of bar charts of questionnaire responses to discuss and predict outcomes

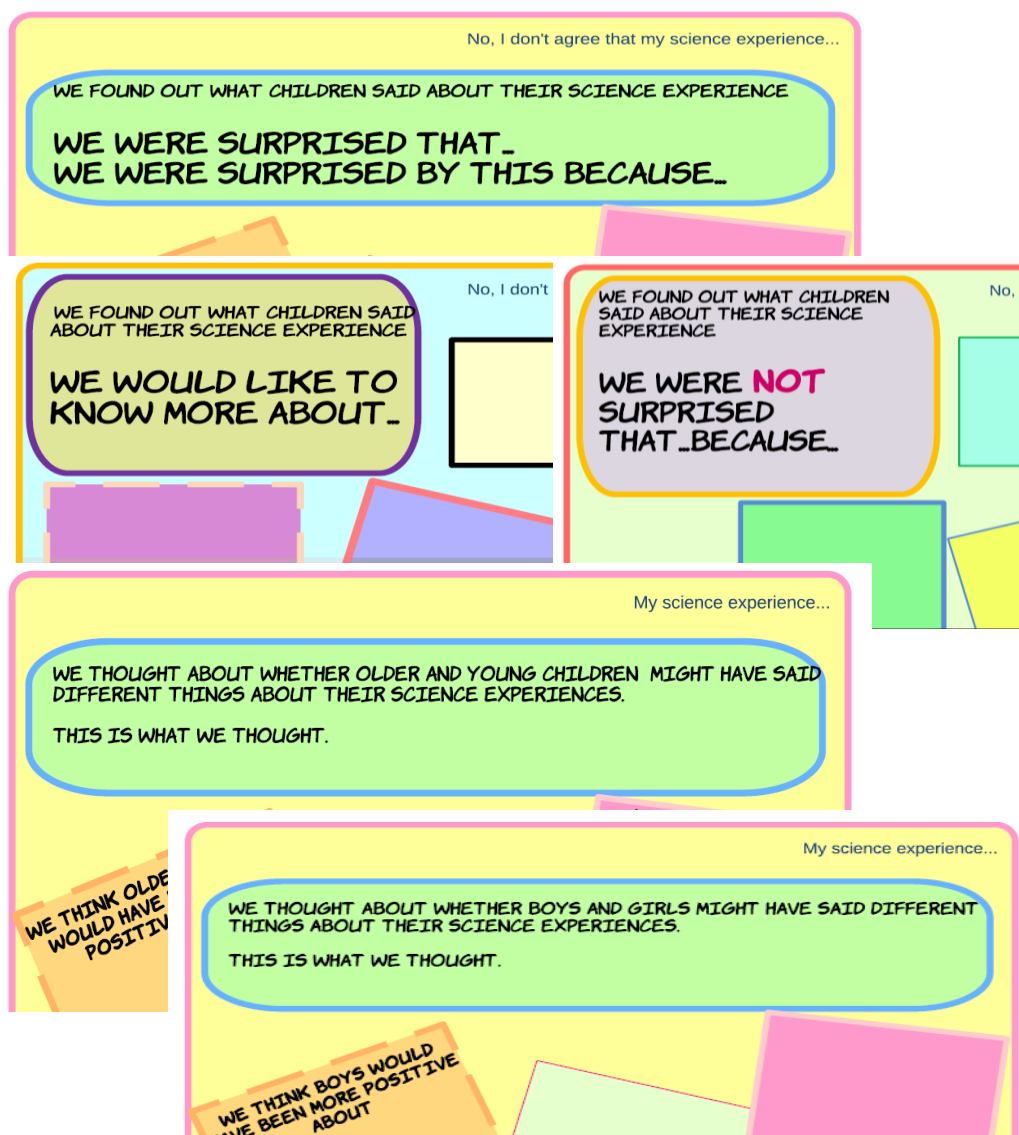


Figure 4.8 Example of approaches to evaluation with CRAG

The order of most to least positive responses for the full sample of responses from participants in primary schools is shown in Table 4.1. The ranking is also included; equal placings indicate that the difference between the percentage of participants agreeing with the statements is not significant.

Table 4.1 Primary-school participants' responses to statements "my science experience..." with CRAG predictions

My science experience...	% selecting "Yes" as response	Actual ranking (n = 532)	Order placed by CRAG
was fun	83	1=	1
was interesting	79	1=	2
encouraged me to explore new things	69	3=	5
encouraged me to be creative	67	3=	4
made me think	65	3=	3
showed me how science affects our way of living	62	3=	8
increased my curiosity	55	7=	10
increased my understanding of the world around me	55	7=	9
made it easy for me to learn	53	7=	6
gave me the chance to use modern technologies	52	7=	7
helped me to think about environmental, technological and scientific issues	48	7=	11
helped me to understand Scotland and its place in the world	45	12	12
made me think about jobs	35	13	13

The CRAG participants' thinking on how the statements would rank in terms of agreement by research participants broadly reflects the responses for the full data collection. The CRAG participants ranked "my science experience showed me how science affects our way of living" two places higher than the research participants and ranked "my science experience made it easy for me to learn" one place lower than research participants. Completing the same exercise for negative responses, the CRAG's ranking matched the data exactly. By facilitating the development of CRAG participants' informed views, the extent to which they can closely predict responses of 'people like them' (Murphy et al., 2013) about their science experiences is evident.

Discussion about the science activities enjoyed by research participants outside school was structured around a 'washing line' activity. Children were invited to hang labelled

'lab gloves' on the washing line to identify the popularity of science activities outside school, ranking from most to least popular (Figure 4.9).

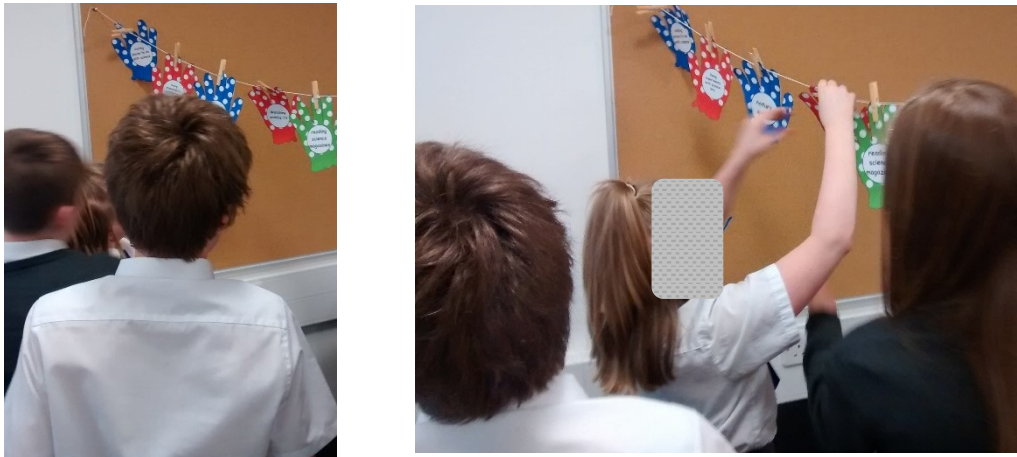


Figure 4.9 Example of approaches to evaluation with CRAG

The CRAG participants discussed their thinking, changing the order on the line and justifying their decisions to one another. I then shared with them a pie chart illustrating participants' responses. The CRAG participants compared and contrasted research participants' responses with their thinking, considering and discussing areas of agreement and disagreement. In pairs or trios, the CRAG participants also considered how these activities might be ordered in the responses from girls and boys, and for older and younger children. Again, considering research participants' responses, the CRAG participants commented on what surprised them, what did not surprise them, and discussed what else they would like to know. They also considered responses to the questions "do you like learning science in school?" and "do you think you are good at science" using visual and text-based discussion prompts. These discussions were recorded in field notes and audio recorded for subsequent transcription.

The CRAG participants' development as coresearchers was evident when observing them working together and with me, on the questionnaire development and the data evaluation activities. In the data-evaluation phase, they were actively involved in looking at the data in a variety of formats and considering what was emerging from it. In CRAG meeting 8 alone, on-task data analysis and evaluation of responses to the open-ended and closed questions lasted for more than 105 minutes. CRAG meeting 7 was not audio recorded however the CRAG participants were engaged in discussion of

responses and data throughout a 90-minute session. Field notes and verbatim transcripts of CRAG meetings, particularly examining the CRAG participants' role in analysing and evaluating the data and identifying next steps for the research, illuminate the progression of the CRAG from echoing others' voices to identifying and defining their own voices, as illustrated by an extract of the transcript from CRAG meeting 8.

Researcher: Can I bring that together then? One of the things that I noticed then, is when I ask you about things that you're very good at, you immediately follow up by saying 'and I like this about them and I like that...'. So, this question "do you think you're good at it?" might also be tied up with how they feel about it, how much they like it, possibly?

CRAG (KB): If we did it again, it would probably be better if we did like 1 to 10...cos that would...

CRAG (AG): On a scale of 1 to 10 how...

CRAG (KB): With like 10 being...

CRAG (CG): the worst

Researcher: Do you think we should have asked that question differently to know more about what the answers meant? So, you're suggesting maybe a scale? Or do you think we should have said to people they could just write, describe how they feel, would that have been better, if I was to do the questionnaire again?

CRAG (XB): Yeah but then I think people kind of get lazy, if you're on that.

CRAG (CG): Let them write their own opinion and then pick the three most popular ones and put that in the next survey.

Researcher: So, you say sort of pilot an open question...yeah okay.

CRAG (CG): Yeah, let them because they might not pick any of them.

CRAG (JB): Some questions just get boring.

CRAG (AG): I don't think you should just like leave it up to them because then they might just say like 'alright, I'm okay' but then, erm, but some people might write like a page-long essay, but some people don't really like doing questionnaires and just kind of...a bit 'yeah I'm alright, I'm ok'...

Researcher: 'Yeah I'm ok' so they're just almost not committing to the questionnaire?

CRAG (AG): Yeah. Giving them options then people can think about it, but they don't have to write their own feelings.

(CRAG meeting 8)

When reviewing visualisation in CRAG meeting 8, participants asked questions about the number of responses and possible responses to better understand the data and inform their thinking. They were examining, challenging and discussing the data and information, rather than waiting for an adult in the group to provide it.

Consideration of the open-ended questions within the research instrument began with a summary of what is already known about science outside school, the key elements of the literature review, as suggested in discussion with Lesley Emerson (formerly McEvoy). The participants' responses were shared in a variety of visualisations, and CRAG participants' discussions captured in field notes and in audio recordings which were subsequently transcribed. Responses to the question "How can science experiences help you learn?" were grouped into "they can help me learn by...", "to help me learn there should be..." and "to help me learn they should be..." and most frequent words identified and counted (Appendix 23). Responses to the question "How do science experiences make you feel about science?" were treated similarly with a count of words used presented in a bar chart. In addition, these responses were grouped into broader themes including answers which indicated greater motivation and a realisation of the wider impact of science (Appendix 24). The CRAG participants considered responses to the open-ended question "how do science experiences make you feel about science?", and the free-space responses. They worked together to explore the data to identify themes, illustrated in the extract of discussions from CRAG meeting 8 included as Appendix 25. As the CRAG participants discussed and grouped the statements to identify themes, I took notes and asked questions to clarify where they were placing statements or the meaning of discussions. In this part of the study, post data collection, the CRAG participants had again progressed through the stages of the ZPD from adult- to self-assistance then to internalisation to **be** coresearchers.

Reflecting on CRAG participation

An element of the children's rights-based methodology is to inform participants of how their contribution has been used and how the research has progressed. CRAG participants were invited to consider being involved in producing a report for research participants who had completed the questionnaire. This invitation prompted CRAG participants to discuss their experiences and reflections on CRAG participation, captured in the field notes of CRAG meeting 8 (Appendix 25) and a poster (Figure 4.11).

It was clear how much value the CRAG participants placed on the experience of being involved in research, both for their science knowledge and their personal development, evidence of the creation of a ZPD in which the intellectual and emotional are inseparable (Kravtsova, 2009; Levykh, 2008). The extent to which the CRAG participants felt that the experience had prepared them for their futures was evident, as they shared and faced concerns they had about making the transition to secondary schools. They felt strongly that others should be given the opportunity, and encouraged, to be involved in research.

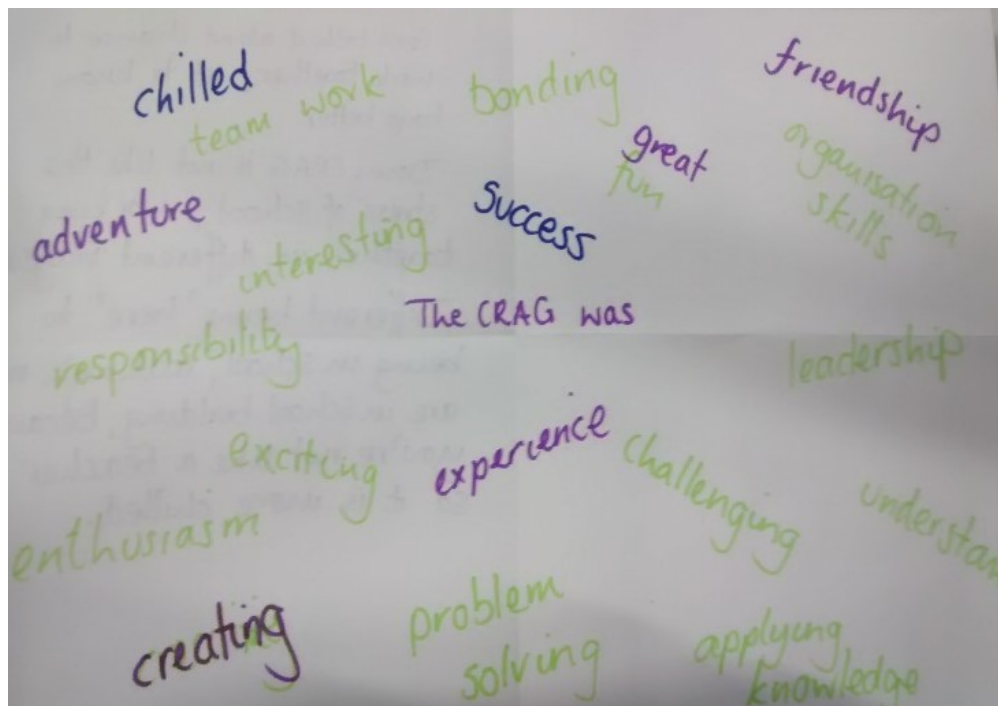


Figure 4.10 Field notes of CRAG meeting 8



Figure 4.11 Children's reflections on CRAG participation

The CRAG participants' discussion as they worked together on the poster, through which these feelings about their CRAG experiences emerged, are illustrated in the following extracts from field notes:

"Doing CRAG is not like the stress of school, working together in different ways. It's different being 'here' to being in school, although we are in a school building, because you're not like a teacher, it is more chilled."

"It gave us a chance to work together, to get to know the boys better."

"Bonding, because doing this stuff together for the few years and then...now we're all going off and then we can always look at it and think of all the people we did it with."

"Learning about science directly... we've learned about science, so when we have a science test, we'll hopefully not fail it."

The original intention was that CRAG meeting 8 would be the final meeting. However, CRAG participants suggested that they could and would like to continue to work with me, to capture and share their experiences. A further two CRAG meetings (9 and 10) were arranged (Appendix 7). The children proposed making videos as the best way to capture their thinking and talk to others 'like them'. They proposed and agreed that these could be made using software on tablets available in the school; the children liaised with school staff and made arrangements to access the tablets and software. Of the original 11 participants, nine attended CRAG meeting 8, with two having left the school. Seven continued to CRAG meeting 9 and five attended CRAG meeting 10 to make videos about their experiences. This was very close to the end of term for the CRAG participants and the end of their time in primary school, hence there were a range of demands on their time. The five who attended meeting 10 decided to split into two groups, which they organised themselves, based on what they wanted their videos to be about. One group chose to make a video about their CRAG experience (CRAG, 2016a)); Figure 4.12 shows the final slide entitled 'CRAG – All About It!' in which they captured their reflections on the experience.

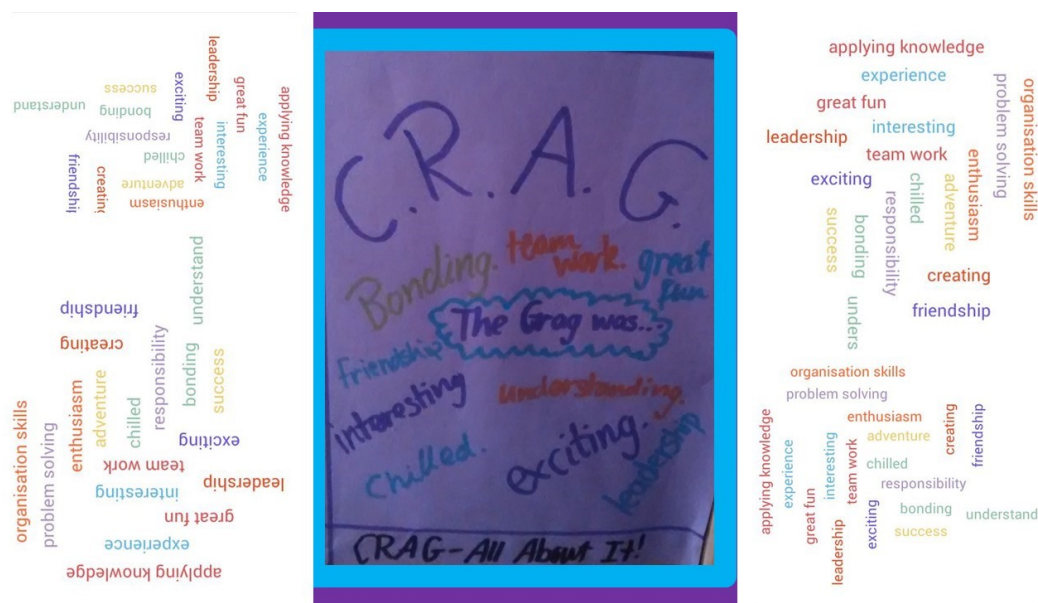


Figure 4.12 Children's reflections on CRAG participation: a still from the video 'CRAG experience'

The other group titled their video ‘CRAG is fab’ (CRAG, 2016b) and included an image based on the poster created in CRAG meeting 8 (Figure 4.11) as shown in Figure 4.13.

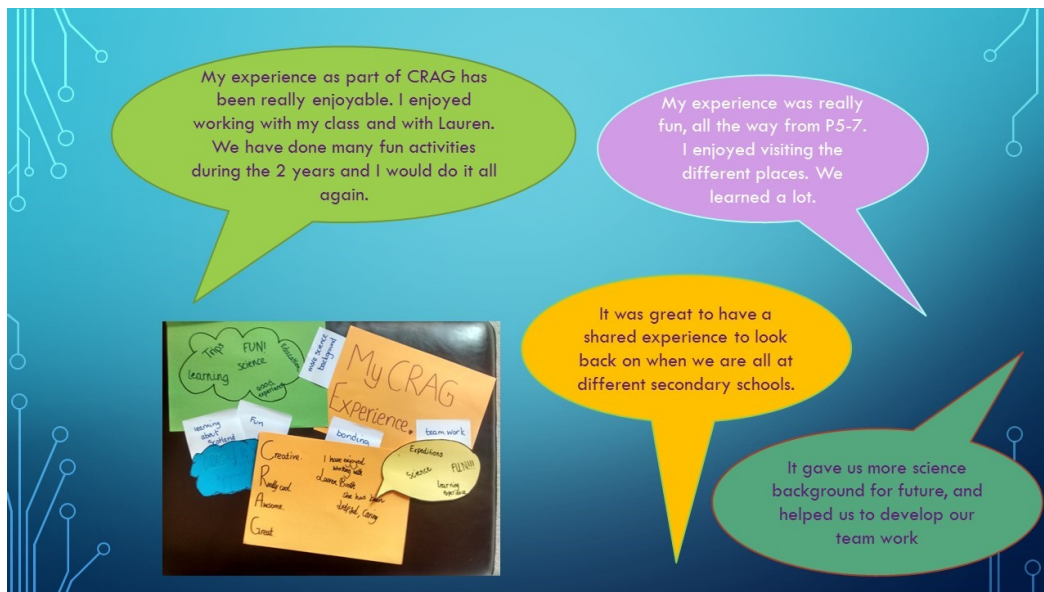


Figure 4.13 Children's reflections on CRAG participation: a still from the video 'CRAG is fab'

In a Vygotskian sense, through the children's rights-based methodology which underpins the CRAG, the participants' are offered opportunities through which they acquire "experience defining themselves that in future will be used independently" (Zaretskii, 2009, p. 84). This was evident both within the research project and also in the CRAG participants' view of the benefits of involvement in the CRAG; specifically, that it had helped to prepare them for the future. Activities which assist the participants in accessing information to develop informed views and the dialogue surrounding these activities, create a ZPD for participants, the zone in which they have potential to develop, with the help of an MKO (Kravtsova, 2009; van Oers, 2007). The participants may have initially identified me as the MKO. However, it soon became evident that they recognised one another as such; "the assistant...becomes the mediator" (Levkyh, 2008, p. 90). This transition from requiring the assistance of an adult, through to internalisation in which the CRAG participants demonstrated their capacity to use and apply their learning, and to reflect and act as MKOs for their peers (Warford, 2011) was supported by the activities designed to develop informed voice. Tharp and Gallimore (1988) identify self-reflection leading to self-assistance as one of the first two, possibly simultaneous stages, of the ZPD the other being teacher-assistance (Warford, 2011). The activities used to provide opportunities for developing informed voice also provided opportunities for self-reflection leading to self-assistance (Tharp & Gallimore, 1988).

In working with the CRAG participants as coresearchers, there was evidence of a symmetrical interpretation of the ZPD as proposed by Roth and Radford (2010). Describing the ZPD as an “interactional achievement” (Roth & Radford, 2010, p. 303), Roth and Radford identify that each word spoken by two participants in an activity in an ‘asymmetric’ teacher-learner relationship is a social interaction accompanied by evaluation. Both participants take the role of teacher and learner, leading to symmetry: “it is the unfolding and unpredictable connectivity that is allowed by the social evaluation of utterances and intentions that ties together, in a reciprocal manner, the participants in a symmetric space of inter-action” (Roth & Radford, 2010, p. 304). The children’s rights-based methodology implemented in my study, in which I strove to remove barriers to children’s participation, to address the power imbalance between our roles and to engage children’s informed voice, aligns with the ‘traditional’ asymmetric interpretation of the ZPD. However, it aligns perhaps more strongly with this symmetric view of the creation of the ZPD. The Roth and Radford (2010) conceptualisation of the ZPD offers an explanation of why the children’s rights-based methodology used in my study works to develop children as coresearchers, particularly where the time period was such that relationships developed with the CRAG participants which allowed for symmetric interactions.

Orienting experiences to the ZPD requires that the child’s individual needs are identified and met, and the children’s rights-based methodology implemented in my research provides structures to do so. Although I drew upon research in developing the structures within which the CRAG’s work progressed, participants’ learning through the CRAG is that which is defined in Vygotskian terms as ‘spontaneous’ (Kravtsova, 2009). The CRAG participants moved to “defining themselves” (Zaretskii, 2009, p. 84) and driving the CRAG meetings, and hence could recognise “themselves as the source” (Kravtsova, 2009, p. 15) of the learning programme undertaken. The structures put in place to meet the four elements of a children’s rights-based methodology (Lundy, 2007) do not negate the spontaneous nature of learning. Learning which is spontaneous in nature need not be interpreted as requiring development without any outside assistance. The conditions for children’s self-definition can be externally imposed and indeed development may rely upon the intervention from another to progress (Kravtsova, 2009; Zaretskii, 2009), such as in the case of this children’s rights-based methodology.

For the age group of the CRAG participants, Kravtsova (2009) argues for communication as the key element of development, requiring children either to “integrate themselves into the context of adults and internally identify with them...(or) use their peers as tools” (Kravtsova, 2009, p. 23). Thus, the CRAG participation itself and the activities designed to enable children to access information to develop informed views, are drivers for the development of higher psychological functions, creating ZPDs for participants in the CRAG (Figure 4.14).

Visualisation of the children’s rights-based methodology within CHT

Figure 4.14 is a visualisation of the creation of ZPDs through CRAG participation. The children’s rights-based methodology is an enactment of CHT. Within the visualisation, this is represented by all elements relating to my research study being placed within the bounds of CHT, indicated by the heavy green line in Figure 4.14. The children’s rights-based methodology is represented by the black line, and the two key elements of the CRAG and assisting children to develop informed views are situated within that methodology.

Participation in the CRAG is represented by a heavy orange line. The line is not solid, because participation in the CRAG does not stand alone. It is not separated from the participants’ other learning, experiences and interactions, in the sense that they will influence the experience in the CRAG and participation in the CRAG will influence, through the development of higher-psychological functions and individual transformation, the participants’ lives beyond the research study.

The lines with arrows at each end represent the two-way symmetrical interactions creating the ZPDs and then through the creation of ZPDs, the development of higher-psychological functions. These interactions can include but are not limited to dialogue. Rather, the interactions encompass the range of intellectual and socio-emotional interactions between humans. The learning which comes through participation in the CRAG leads development and this development pushes the boundaries of what the children can do within their participation in the CRAG. As their participation continues, further learning and deeper learning occurs, which expands the boundaries of the ZPD and the development of higher-psychological functions and so on, in line with the proposition of Zaretskii (2009) that as the child interacts with an adult, the ZPD expands:

“in other words, not only can children do more independently; what they can do in interaction with an adult also expands” (p. 80).

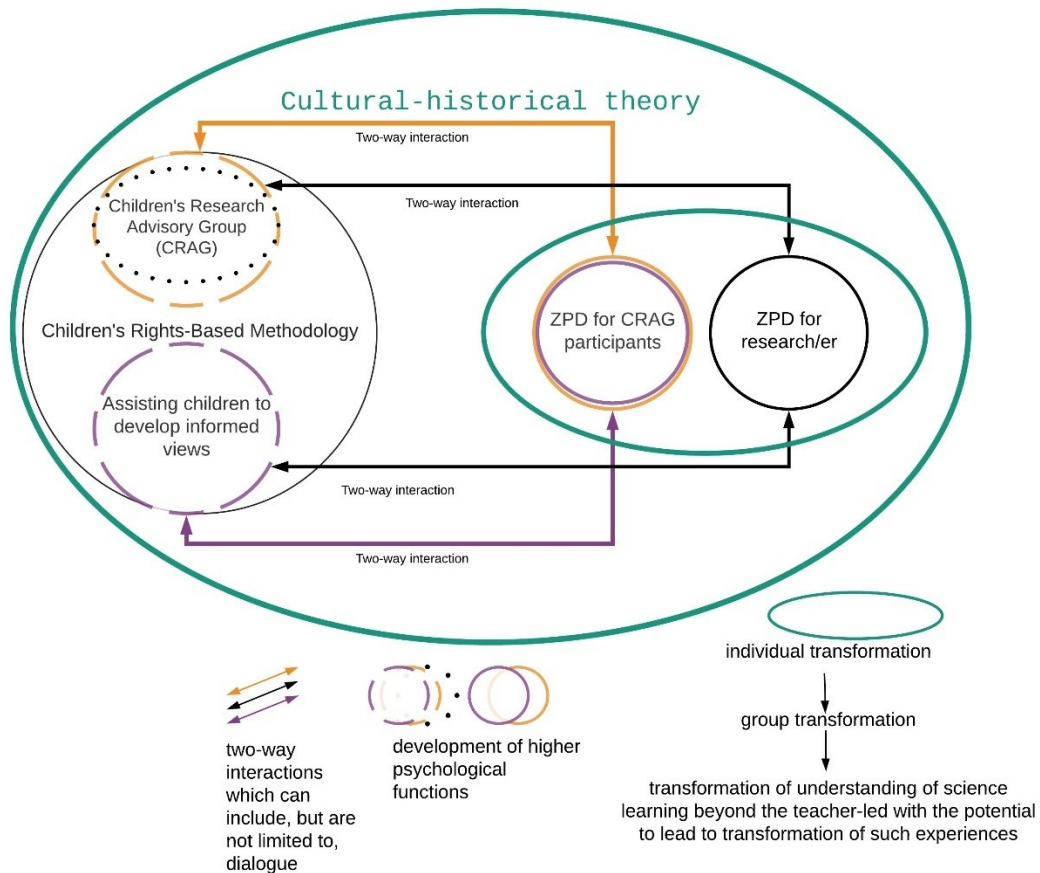


Figure 4.14 Visualisation of the creation of ZPDs through children's rights-based methodology

A three-dimensional representation of this **spiral of mutual interaction**, through which the boundaries of participation and learning, the ZPD and the development of higher-psychological functions are continually expanded is shown in Figure 4.15. Figure 4.14 can be considered as an aerial view, whilst Figure 4.15 represents what would be seen if we were able to view a horizontal 'slice' of the visualisation. The arrow on the left is labelled 'increasing experience' because the benefits of social learning do not come automatically, or indeed easily. The increase is not just about the time spent, but about the careful design of activities to develop the CRAG participants as coresearchers (Davydov & Kerr, 1995) and MKOs (Tharp & Gallimore, 1988) for the researcher and

research, and to assist the CRAG participants in developing informed views to act as MKOs for the research participants.

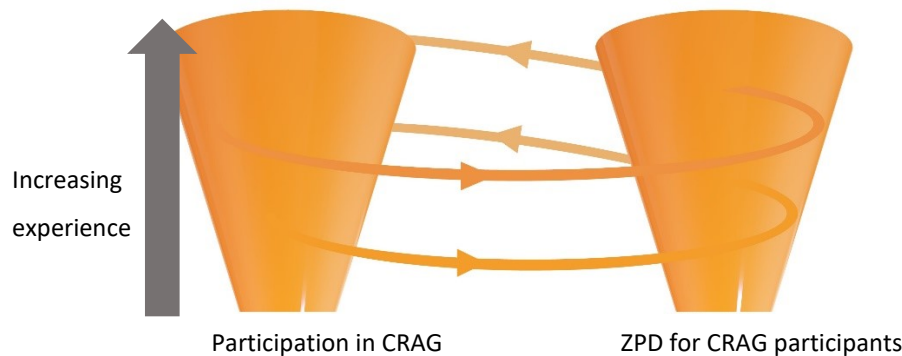


Figure 4.15 3D visualisation of the two-way interaction between CRAG participation and creation of ZPDs for CRAG participants ¹⁴

Referring to the ZPD as “the intellectual actions and mental functions that a child is able to use in interaction, where independent performance is inadequate” (Chaiklin, 2003, p. 9), a children’s rights-based methodology offers opportunity to develop the participants’ maturing higher-psychological functions, “human forms of mind related to the...(sharing) of cultural environment...(and) social relationships of people” (Toomela, 2016, p. 97). Higher psychological functions emerge through social cooperation in the first instance, before developing in the individual (Vygotsky, 1932, in Leontiev and Luria, 1956 in Toomela, 2016). The CRAG participants’ description of their experience (see *Reflecting on CRAG participation* in chapter four) captured this; the development of their higher-psychological functions through social interaction, the social nature through which they have grown “into the intellectual life of those around them” (Vygotsky, 1978, p. 88). Whilst Vygotsky’s focus was on the adult as a more competent other, modelling the ‘ideal’ to which children strive, the CRAG participants have illustrated that through collaboration within the structures of the CRAG they can act as more knowledgeable peers (Tudge, 1990).

¹⁴ The 3D cones used within Figure 4.15 were created by kaithekiller922 in Microsoft Remix 3D and shared within the Remix 3D network community on 20 April 2017. The terms and conditions of the Remix 3D network community, a free and open space for sharing, permit free, royalty free and worldwide use, saving, reproduction, broadcasting, transmission, sharing and displaying with attribution.

The same 'mechanism' exists for the adult coresearcher participating in the CRAG. The adult coresearcher's participation in the CRAG is represented in Figure 4.14 by a dotted black line. Again, the line is not solid because participation in the CRAG does not stand alone. The black lines with arrows at each end represent the two-way symmetrical interactions creating the ZPDs and then through the creation of ZPDs, the development of higher-psychological functions.

In simple terms, the CRAG participants learn from the researcher, expanding what they can do within the CRAG participation, and the researcher learns from the CRAG, pushing the boundaries of his or her learning and hence development. CRAG participants act as the MKO (Tharp & Gallimore, 1988) in their lived experience and experience as 'people like them' (Murphy et al., 2013). This two-way interaction is represented in three-dimensions in Figure 4.16.

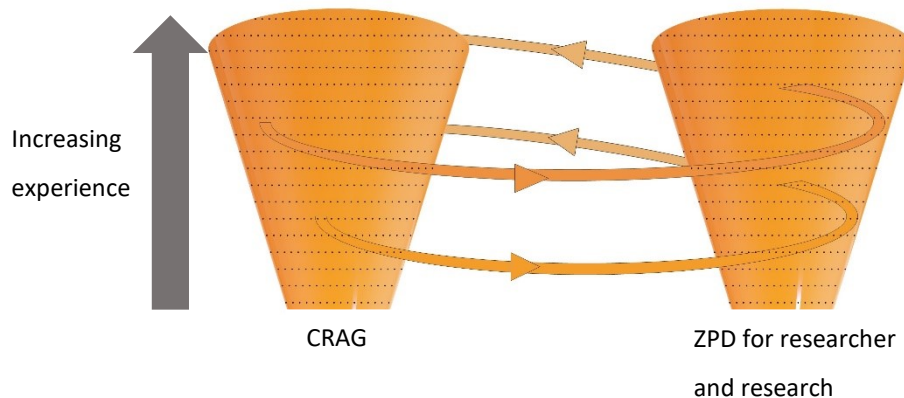


Figure 4.16 3D visualisation of the two-way interaction between CRAG participation and creation of ZPDs for researcher and research¹⁴

I would capture this in my personal experience by saying that working with the CRAG participants provided so much learning for me and such insight into the CRAG participants and 'people like them' (Murphy et al., 2013) that it extended my development and the boundaries of my ZPD in terms of who I am as a researcher and practitioner, including my values and beliefs. This then took me further in my work with the CRAG and extended the experience of participants in the CRAG. From a personal perspective, I can attest to the experience of this two-way interaction through the children's rights-based methodology leading to my individual transformation which then led to group transformation, considering the CRAG participants and me as a group.

These transformations have impacted upon my role as a teacher educator, the ZPDs created for student teachers and qualified teachers who undertake learning with me, and hence comes the wider, societal impact, envisaged by Vygotsky.

The black line in Figure 4.14 also represents this mechanism for the **research**. The children's rights-based methodology used within the research informs and extends the participants' experience within the CRAG which in turn pushes the boundaries of the ZPD for the research. Again, this two-way interaction which can be represented in three-dimensions (Figure 4.16). In this three-dimensional representation the layering of the black lines over the orange relating to the participants in the CRAG illustrate that these mechanisms are taking place at the same time.

The mechanisms around creation of ZPDs for the participants, researcher and research through assisting the development of informed voice can be described in the same way (Figure 4.14).

In a cultural-historical sense, individual transformations lead to group transformation and ultimately transformation of the research into science learning. The children's rights-based methodology creates opportunity for individual transformation. It also creates and supports an intermediate step between individual and societal transformation: the transformation of the group.

Creating ZPDs for research participants

Assisting in accessing information to develop informed voice

The questionnaire included responses to questions from 'some children' (Figure 4.17). These responses were developed from the CRAG participants' completion of the pilot questionnaire in CRAG meeting 4 (Appendix 13, Appendix 14) and from discussions as part of the activities during CRAG meetings 1 to 4. Following a pilot of the questionnaire with 42 children (see *Questionnaire pilot* in chapter three), the responses were further developed and agreed with the CRAG participants at meeting 5. Figure 4.17 is an extract from the questionnaire: what 'some children' said in response to the open-ended question "how do your science experiences make you feel about science?"



Figure 4.17 Extract from questionnaire (question 5)

The inclusion of these statements by ‘some children’ creates a dialogue or collaboration crucial to development of a ZPD (Chaiklin, 2003; Levykh, 2008; Roth & Radford, 2010) between the CRAG participants and research participants. It creates an opportunity through which the CRAG participants as peers of the research participants are tools (Kravtsova, 2009) for the research participants. Collaboration in a Vygotskian sense is not a “joint, coordinated effort to move forward” (Chaiklin, 2003, p. 11) but rather it is an interaction, providing an opportunity for “intellectual imitation” (Vygotsky, 1984 in Zaretskii, 2009, p. 75). By imitation, Vygotsky did not mean copying but rather assistance through a reasoned “intellectual operation” (Vygotsky, 1984 in Zaretskii, 2009, p. 74).

By involving children as coresearchers who act as the MKOs (Tharp & Gallimore, 1988) or tools (Kravtsova, 2009) for research participants, the questionnaire content and presentation is appropriate to the maturing functions of the age group. Where maturing functions are present, research participants can take advantage of the assistance offered (Chaiklin, 2003). Thus, the interaction between the CRAG and the research participants, via the design and content of the questionnaire and the statements from ‘people like them’ (Murphy et al., 2013) creates a ZPD. The ZPD is viewed not as a mechanism or a tool, but rather the ZPD describes the potential for development through interaction or collaboration in its broadest sense (Zaretskii, 2009). It must be recognised that simply pairing a ‘more competent’ child with a ‘less competent’ peer does not guarantee the creation of a ZPD, or the cognitive benefits of

social as opposed to individual learning (Tudge, 1990). Through application of the children's rights-based methodology, interactions and collaborations are carefully designed to create a ZPD and confer the benefits of social learning. This applied as much to the interactions with the research participants as with the CRAG participants, through commitment to appropriate content, design, and layout of the questionnaire and communication of the invitation to participate and research aims.

Benefits of children's rights-based methodology for research participation

In total, 92% of questionnaires were returned, either fully or partially completed. This response rate compares favourably with a large-scale study of children's perceptions of residential fieldwork carried out in England in 2012 (Amos & Reiss, 2012). In this Amos and Reiss (2012) study, questionnaires were used prior to and following an immersive residential fieldwork experience. Teachers were asked to ensure completion of pre-course questionnaires; the return rate of pre-course and post-course questionnaires was 62% and 43% respectively (Amos & Reiss, 2012).

The response rate for my research compares with the RIPPLE (Randomised Intervention of Pupil Peer Led Sex Education) study, a large-scale questionnaire-based study carried out with 4754 13-14 year olds in state schools in England (Strange, Forest, Oakley & The Ripple Study Team, 2003). This large-scale study, in which there was a 92 – 93% completion rate, led to an examination of the influence of social context on questionnaire completion. In the study, participants were advised of their right not to take part, and Strange et al. (2003) also described being keen to avoid establishing a 'teacher-pupil' relationship. However, the need for teachers to be motivated to "ensure that students completed the questionnaire" (Strange et al., 2003, p. 339) suggests some obligation or requirement was conveyed to participants. Students absent when the questionnaire was completed were identified and followed up, with the majority subsequently completing it. In one school participating in the study, 180 students simultaneously filled in the questionnaires in conditions established for an external examination. Unsurprisingly this was met with the students' "collective resistance and a reluctance to complete the questionnaire" (Strange et al., 2003, p. 334), arguably affecting the validity of the responses completed under such conditions. In my research, every effort was made to avoid conveying a sense of obligation. Despite this,

a return rate of 92% was achieved, emphasising the value of children's voice in the research process when working with 'people like them' (Murphy et al., 2013) as research participants.

The most recent, large scale survey of the views of children in Scotland on their science education¹⁵, including attitudes to science, technology and the environment was carried out in 2006. It was undertaken with pupils in their third year of secondary education, as an extension to the *ROSE* survey (Farmer et al., 2006). Within this, when children chose not to answer questions on a page, the whole questionnaire was rejected. Questionnaires were also rejected on the grounds of not being "reasonably completed" (Farmer et al., 2006, p. 8) although the meaning of this phrase is not explored within the published methodology of the survey. Approximately 5% of questionnaires were rejected. Thus, only those choosing or able to complete the entire survey in the time permitted or available had their voices heard. The majority of the rejections came from what are described in the report as lower academic levels. Almost 9% of submissions from candidates studying for Intermediate 1 qualifications were rejected, compared with only 0.5% of those studying for the more academically demanding Intermediate 2 qualifications. Arguably, this could have led to the outcomes of the survey affirming the status quo (Fielding, 2001c) for learners for whom the system already works well and suppressing the voice of those for whom it does not. Throughout the analysis, there is a focus on social class, although the reasons for this focus are not articulated. Conclusions and assertions do not draw on evidence. For example, "pupils choosing two or three science subjects at S3/4 come from higher socioeconomic backgrounds making them more likely to value education and learning generally" (Farmer et al., 2006, p. 36) appears to be an assumption based on conscious or unconscious biases. More recent research develops the idea of science capital being linked to science aspirations (see for example Archer et al. (2013a)), with a higher proportion of those with high science capital reporting science or STEM-related career aspirations.

Within my study, with a children's rights-based methodology, no responses were rejected. Nor were judgements or assumptions made about children's intentions. Key to the children's rights-based methodology is respecting children's rights to participate

¹⁵ This survey included interest in learning about science, reaction to science at school, career ambitions and out of school experiences and activities.

to whatever extent they wish. Additionally, it must be recognised that children's 'silence' by means of non-response to a question is a legitimate and important part of their contribution (Lewis, 2010). In the video for children inviting participation in the research (Appendix 10) it was emphasised that children could complete as many questions as they wished and need not complete every question. Thus, I did not exclude questionnaires which were partially completed, and I valued the voice of all who participated.

Within the questionnaire there were three open-ended questions: "how do your science experiences make you feel about science?" (question 5) (Figure 4.18); "how can science experiences help you learn?" (question 6); "what could science experiences do to help you enjoy science more?" (question 7). In addition, a space was provided for participants to write or draw "anything else you would like to tell us about science or science experiences".



HOW DO YOUR SCIENCE EXPERIENCES MAKE **YOU** FEEL ABOUT SCIENCE?
TELL US!

Figure 4.18 Extract from questionnaire (question 5)

For each of the open-ended questions, research participants were asked to review a range of views expressed by 'children like them' (see, for example, Figure 4.19) and to tick or otherwise mark these to indicate agreement with any, some or all of these views. Agreement or otherwise was not recorded; the presence of ticks or other marks was taken to indicate engagement with these children's views. From a cultural-historical perspective, agreement may be helpful in supporting the research participants to form and express their views; it can be described as a "safe and emotionally positive collaboration" which provides motivation (Levykh, 2008, p. 92). Equally, disagreement

may be valuable, providing the “dramatic collision” (Veresov, 2004, p. 6) which Veresov (2004) describes as experiencing opposing opinions, leading to self-reflection.

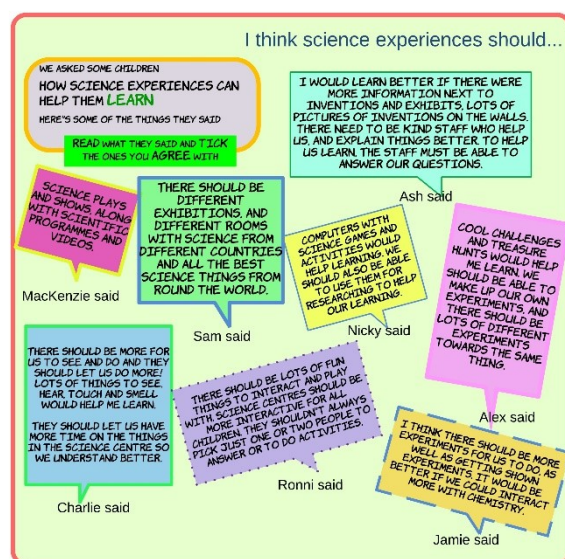


Figure 4.19 Extract from questionnaire (question 6)

Responses to question 5 ‘feel’ were longer than those for question 6 ‘learn’ and 7 ‘enjoy’ (Table 4.2).

Table 4.2 Word count and word length in open-ended question responses

	Qu 5 ‘feel’	Qu 6 ‘learn’	Qu 7 ‘enjoy’
Total number of responses	933	826	804
Mean number of words per response	12.8	11.6	9.9
Average word length (characters per word)	4.2	4.4	4.4

Response rates for the open-ended questions are shown in Table 4.3. There are fewer responses to question 6 than question 5 and to question 7 than question 6.

Table 4.3 Response rates for open-ended questions

	Qu 5 'feel'	Qu 6 'learn'	Qu 7 'enjoy'	Qu 8 'anything else'
Total number of responses (n =)	33	826	804	493
% response rate ¹⁶	89	79	77	47
Significance of difference in response rate between question 5 and question 6 ¹⁶		*		
Significance of difference in response rate between question 5 and question 7 ¹⁶				

There are a number of possible explanations for reduced response rates and shorter responses for questions 6 and 7 compared with question 5. Participants may not have had sufficient time to complete questions 6 and 7, or it may be an indication that they found the questionnaire too long. However, it may also be that these were the most 'difficult' questions to answer. Question 5 asked participants how they feel about science experiences, whereas questions 6 and 7 sought suggestions and ideas for what could be done to help enjoyment and learning of science. It may be that participants legitimately felt they had less or nothing that they wanted to say in response to questions 6 and 7. The length of responses can be considered to give some indication of engagement with the questions, and it is worth noting that some responses were in excess of 40 words.

For open-ended questions 5 and 6 and the invitation to share any other comments or thoughts about science or science experiences (question 8), more female participants responded than male participants, with differences either significant or highly significant (Table 4.4). For question 7, more female participants responded than male participants, although the p-value was just outside the range of significance.

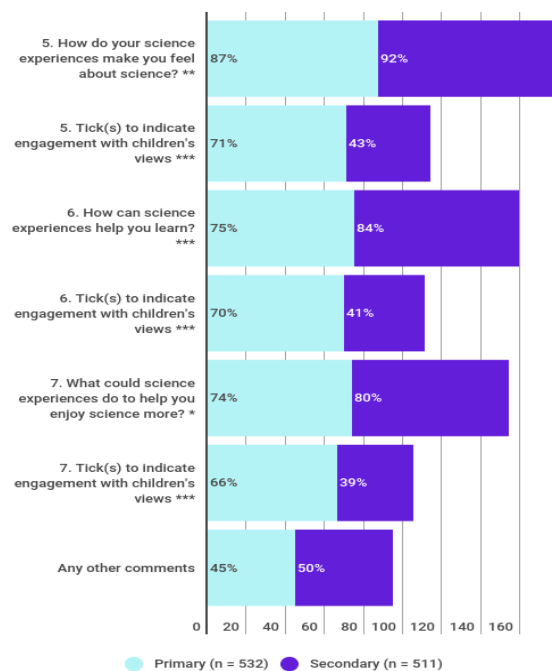
¹⁶ Based on 1043 fully or partially completed questionnaire, significance calculated using a one-sample t-test between proportions

Table 4.4 Gender breakdown of response rates to open-ended questions

% of participants responding	Male (n = 539)	Female (n = 491)	Significance
5. How do your science experiences make you feel about science?	87	93	**
Tick(s) to indicate engagement with children's views in question 5	53	63	**
6. How can science experiences help you learn?	78	83	*
Tick(s) to indicate engagement with children's views in question 6	52	60	**
7. What could science experiences do to help you enjoy science more?	75	80	p = 0.0557
Tick(s) to indicate engagement with children's views in question 7	49	56	*
8. Any other comments	43	52	**

Strange et al. (2003) identified that completion rates of the questionnaire used in the RIPPLE study were lower for male respondents, compared with female respondents, with the difference highly significant. Information is not available on the format of the questionnaires used. The figure for completion in the Strange et al. (2003) study was based on those “finishing the questionnaire” (p. 341); it is not clear what is meant by ‘finishing’. However, this gives an indication that the higher percentage of female participants than male participants completing questions is not out of the ordinary and perhaps not attributable to the use of a children’s rights-based methodology.

For each of the open-ended questions in my study, there are differences between the percentage of participants in primary school and in secondary school responding (Figure 4.20 and Table 4.5).



* significant (< 0.05), ** highly significant (< 0.01), *** very highly significant (< 0.001)

Figure 4.20 Responses to open-ended questions by primary-secondary sector

Table 4.5 Primary-secondary sector breakdown of responses to open-ended questions

	% participants responding		Significance
	Primary (n = 532)	Secondary (n = 511)	
5. How do your science experiences make you feel about science?	87	92	**
Tick(s) to indicate engagement with children's views in question 5.	71	43	***
6. How can science experiences help you learn?	75	84	**
Tick(s) to indicate engagement with children's views in question 6.	70	41	***
7. What could science experiences do to help you enjoy science more?	74	80	*
Tick(s) to indicate engagement with children's views in question 7	66	39	***
8. Any other comments	45	50	not significant

For each of the open-ended questions, a greater percentage of participants in secondary schools than participants in primary schools responded. This may be related to the demand of answering such questions or it may be indicative of the time required to complete the questionnaire. More primary-school than secondary-school participants indicated engagement with the views of other children. In each case these differences were very highly significant. The statements of 'some children' for use in the questionnaire and consideration by research participants were written by the CRAG at the end of primary 5, when aged 9 – 10 years old. The intention of these statements was to support participants in primary schools in developing informed views, as part of the children's rights-based methodology employed in my study. These also formed the first stage of the ZPD for research participants: assistance from a 'teacher' or MKO (Gallimore & Tharp, 1990).

In creating a ZPD, the "field of sense" (Veresov, 2004) is important. Veresov (2004) illustrates the meaning of this, explaining a scenario where a teacher poses a mathematical problem for a child:

“Teacher: Suppose you have two apples. Then you give one apple to someone. How many apples will you have?

Child: Two apples.

Teacher: How come?

Child: I never give my apples to anyone.” (p. 13)

Veresov (2004) explains that this child is approaching this task through “the ‘glasses’ of his personal sense” (p. 13). The child is introducing his personal attitude: “I never give my apples to anyone” (p. 13). Thus, he gives an answer which is mathematically incorrect. What the child has done is to work independently to resolve the contradiction between the task as posed and his personal sense and respond accordingly. We subsequently discover that the child is able to solve the mathematical problem when the question is posed “Somebody has two apples. Then he gives one to you. How many apples will he have after that?” (p. 13). However, in its initial framing, the task is not within the child's ZPD. Thus, in a questionnaire designed for participants in secondary schools, aligning with a children's rights-based methodology, views written by children of secondary-school age may prompt greater engagement with this aspect.

Through the children's rights-based methodology, children as coresearchers are peers of and tools for the research participants (Kravtsova, 2009). Research participants develop informed views by engaging with 'people like them' (Murphy et al., 2013) who, in turn, have engaged with the substantive issues of the research (Lundy & McEvoy, 2011). Within the context of CHT, the role of language to mediate social interaction is foregrounded in the process through which the children's rights-based methodology creates multiple ZPDs. Within each ZPD, individual transformations take place as individuals develop higher-psychological functions through dialogue or, more broadly, through communications or interactions. Using short speech bubbles containing what 'some children' said, the contents of which were developed by the CRAG participants (see, for example, Figure 4.21), there is a dialogue between the CRAG participants, as MKOs (van Oers, 2007), and the research participants. Through the written questionnaire responses, there is a dialogue between the research participants and the CRAG participants. Thus, there is a two-way interaction which creates ZPDs for the research participants and for the CRAG participants.

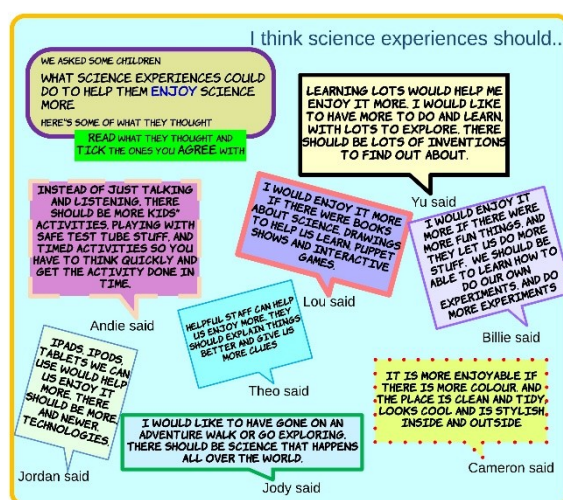


Figure 4.21 Extract from questionnaire (question 7)

Crucial to the creation of the ZPD is that it develops higher psychological functions which are there as "buds" (Vygotsky, 1978, p. 86). Children as coresearchers advised on how best to engage with other children on the issues being researched (Lundy & McEvoy, 2011), identifying themes to be explored within the research by providing insight on issues relating to the research questions, and co-designing the research instrument (Murphy et al., 2010). Through this they were connected to 'people like

them' (Murphy et al., 2013), the research participants. As the CRAG participants developed higher-psychological functions through research involvement, they also interacted with research participants to develop such functions in other children.

The mechanisms associated with creation of ZPDs for research participants are closely interrelated with the mechanisms associated with the creation of ZPDs for CRAG participants, the adult coresearcher and the research. This can be brought together in a single visualisation (Figure 4.22) which is discussed further in the next section.

Children's rights-based methodology as an enactment of CHT

I offer an overview of the children's rights-based methodology originated by Lundy (2007) and Lundy and McEvoy (2011) as an enactment of CHT (Figure 4.22). Earlier in this chapter (see *Visualisation of children's rights-based methodology within CHT in Creating ZPDs for CRAG participants*) I explained the methodology as an enactment of CHT for CRAG participants, the adult coresearcher and the research. In Figure 4.22 I incorporate the research participants into this visualisation. The visualisation of the creation of the ZPD for CRAG participants (Figure 4.14) is extended to incorporate the creation of ZPDs for research participants (Figure 4.22) and to illustrate how the involvement of children as research participants further extends the learning and development of the CRAG participants, researcher and research.

The main element to the creation of a ZPD for children as research participants, represented by the red circle in Figure 4.22, is the establishment of the CRAG as coresearchers with expertise in the substantive issues of the research (Lundy & McEvoy, 2011) and with expertise as children with contemporary experience in peer groups similar to 'people like them' (Murphy et al., 2013). The two-way interaction denoted by the red line with arrows at each end illustrates that the children participating in the CRAG learn from and hence are developed by the involvement of children as research participants. Where there an opportunity or need to continue working with the CRAG and the children as research participants, it might be reasonable to expect to see the 'spiral of mutual interaction' to which I earlier referred (see p. 141) in relation to the two-way interaction between the establishment of the CRAG within the children's

rights-based methodology, CRAG participation and the CRAG participants, and the ZPD for CRAG participants.

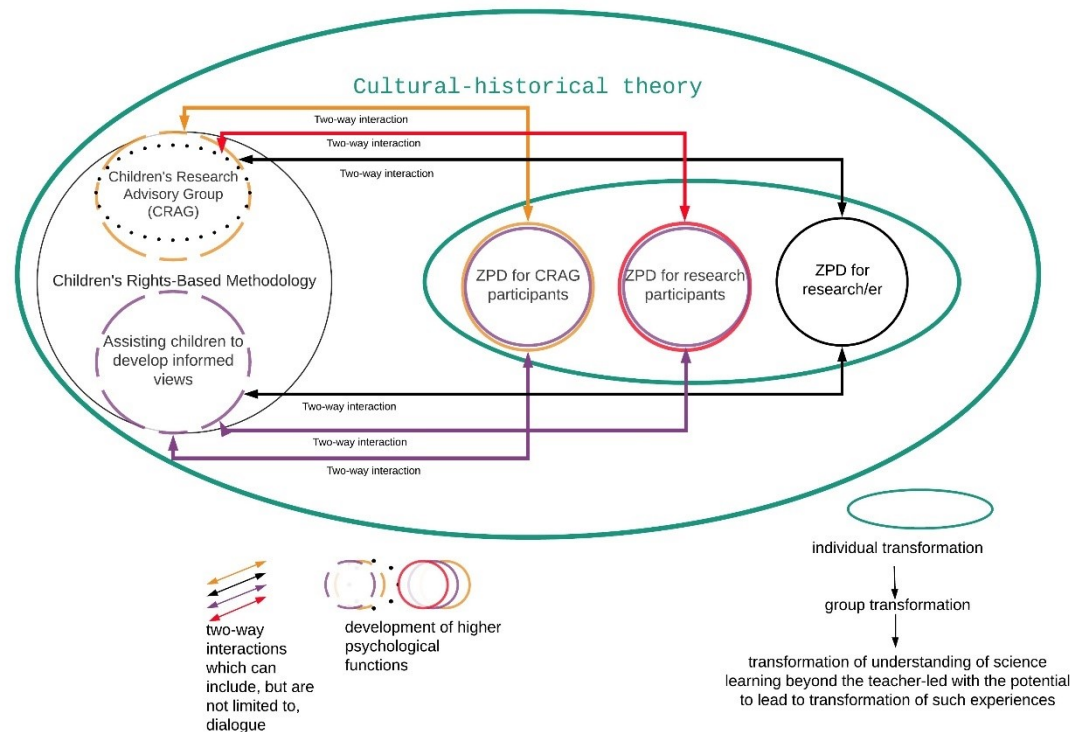


Figure 4.22 *Visualisation of the children's rights-based methodology as an enactment of CHT*

However, in my research study, there was not a repeated cycle of interaction. The process began with the participants of the CRAG contributing to the creation of a ZPD for research participants. The central focus of this was the role of CRAG participants in assisting children as research participants to develop informed views, thus extending the boundaries of the ZPD for research participants. In turn, the involvement of children as research participants through completion of the questionnaire extended the boundaries of the ZPD for CRAG participants and extended the boundaries of their work within the CRAG. The CRAG participants were not only thinking of what 'people like them' (Murphy et al., 2013) might say but indeed examining what people like them did say and this learning further led their development as coresearchers. Thus, the mechanisms described earlier connecting the CRAG participants, the adult coresearcher and the research (see *Visualisation of children's rights-based methodology within CHT* in *Creating ZPDs for CRAG participants*) are extended and enhanced.

For the research participants, whilst there is 'audience and influence' (Lundy, 2007), here the 'spiral' comes to an end. The opportunity for individual transformation is arguably and perhaps inevitably much more limited for research participants than CRAG participants, as is the opportunity or perhaps likelihood of a group or societal transformation. To achieve greater benefit from research involvement for the individual and hence society would, I suggest, require more frequent exposure and involvement in research in this way. By participating more frequently in research framed within CHT and using a children's rights-based methodology, research participants would have opportunity to learn about a range of substantive issues within research and to influence research and perhaps policy or action on these issues. Viewing the group transformation as an intermediate step within the cultural-historical view of the connection between individual and societal transformation, sufficient individuals developing higher-psychological functions and the consequent group transformations, leads to the transformation of 'society'. In the case of my research the transformation in understanding of science learning beyond the teacher-led can be considered the transformation of 'society'. For research participants, I suggest that repeated opportunities to be involved in research using a children's rights-based methodology would provide greater opportunity for individual development and development within the group, perhaps introducing a mindset of a 'learning and researching' classroom or school. There is more likely to then be a transformational impact on society, through the children as research participants understanding the power of their engagement with research and their power to influence matters both within and beyond their lived experience. It may, for example, lead to children less likely to accept 'tokenistic' pupil councils who are involved only in peripheral matters with permission of adult gatekeepers.

The 'learner at the centre' through a children's rights-based methodology

In this chapter, I have discussed the experiences of the CRAG participants and of working with the CRAG and children as research participants. The children's rights-based methodology involving the CRAG was developed and extended for use in my study from the work of Lundy (2007) and Lundy and McEvoy (2011). It was informed

particularly by the use of this methodology with children in the relevant age group in a study by Murphy et al. (2010), involving around 1000 children in primary and secondary schools in England and Wales to explore a topic central to learning and teaching in school science (Murphy et al., 2010; Murphy et al., 2013).

My research study adds to the growing body of evidence (see, for example Emerson, Lloyd, et al. (2014); Lundy (2012, 2016); Marshall et al. (2015); Murphy et al. (2013); Orr et al. (2016); Welty and Lundy (2013)) that children can be engaged with research and as coresearchers in issues beyond their lived experience, in which they may not have previously formed a view. I have presented a model of the children's rights-based methodology developed by Lundy (2007) and Lundy and McEvoy (2011) as an enactment of cultural-historical theory through which ZPDs are created for children as coresearchers through CRAG participation, children as research participants, adult coresearchers and research (see *Creating ZPDs for CRAG participants*, *Creating ZPDs for research participants* and *Children's rights-based methodology as an enactment of CHT* in chapter four).

My study is unique in that the work with the CRAG took place over a period of more than two years. Through this it was possible to observe the four stages of the ZPD proposed by Tharp and Gallimore (1988) as children developed from a reliance on assistance of the adult coresearcher to self- or peer-assistance, to internalisation in which they **became** coresearchers, and recursion, where they needed to return to adult, self- or peer-assistance to progress. Similarly, for me as an adult coresearcher. I was reliant on the CRAG participants as MKOs (Tharp & Gallimore, 1988) in the first instance, having no ideas of their stance and views or those of 'people like them' (Murphy et al., 2013). Through working with the CRAG, I was able to move to self-assistance and then to some degree, internalisation, although there was frequent recursion requiring further input from CRAG participants.

Undoubtedly, working with children as coresearchers presents challenges in terms of logistics and feasibility. The completion of my research as a part-time, self-funded doctoral student offered greater opportunity than might have been available in a shorter-term, funded research project. I was more able to work around restrictions on the availability of children participating in the CRAG. For example, the CRAG

participants were available only between 09:00 and 15:00, in term-time and Monday to Friday. There is a long lead-in time between planning children's rights-based work with children and carrying it out. Ethics procedures are rightly more stringent when working with children and in Scotland, ethical approval to carry out research must be sought from the relevant local authority and Head Teacher in addition to approval from the relevant higher education institution. This was less problematic for me because I was self-funding and part-time. I was not under any pressure to 'cut corners' by, for example, reducing involvement of the CRAG to speed up the process. Without question, the prolonged involvement of the children in the CRAG has made this research and thesis what it is. The approach used has truly placed the 'learner at the centre' and hence there is new insight into children's perceptions of and aspirations for science experiences.

Does this mean that the methodology can work only over such a prolonged period? Not necessarily. My study shows that working with the CRAG participants over a prolonged period gives greater opportunity for the children and adult coresearchers to adapt, extend and develop the research. My original proposal was to explore the perceptions of science experiences of children in upper primary school who would predominantly be aged 9-11 years. However, through the interpretation of the CRAG participants and their questions and insight, the study was extended to include children in the first two years of secondary school. The report for children who were research participants was not a written report, largely authored by me and checked over by the CRAG. Instead two videos were authored, filmed, produced and edited by the CRAG participants, at their suggestion.

The mechanisms through which CRAG participation creates ZPDs for the participants and extends the 'spiral of interaction' (Figure 4.23) were discussed earlier in the chapter (see *Visualisation of the children's rights-based methodology within CHT*). Increasing experience, indicated by the grey arrow on the left-hand side of Figure 4.23, is a combination of both time of exposure and the types of interactions to which the participants are exposed. Lundy (2007) did not specifically allude to the time period required for this methodology. However, Lundy's enactment of Article 12 of the UNCRC specifies four required elements: space, voice, audience and influence (see *Children as coresearchers: Children's Research Advisory Group* in chapter three). This is not

something which can be done in, for example, a single meeting in which children meeting coresearchers for the first time.

It is reasonable to assume that if the involvement of the participants is shorter, as indicated by the dashed black line in Figure 4.23, then the benefits conferred for participants, coresearchers and research will be lessened. I have discussed this from the perspective of involvement of children as research participants earlier in this chapter (see *Children's rights-based methodology as an enactment of CHT* in chapter four). Further research might explore what this minimum time period could be for CRAG participants, adult coresearchers and research, and whether repeated involvement in research with a children's rights-based methodology confers greater benefits for research participants than involvement in a single research project.

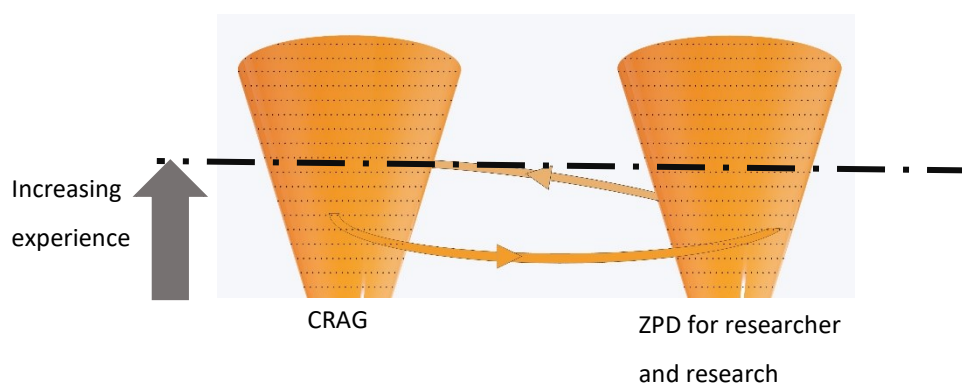


Figure 4.23 3D visualisation of a limited experience two-way interaction between CRAG participation and creation of ZPDs for researcher and research¹⁴

The benefits of the children's rights-based methodology for the CRAG participants, adult coresearcher and research are dependent on the opportunity to develop relationships which allow for symmetric interactions (Roth & Radford, 2010) between the children and adults as coresearchers. However, the benefits do not arise simply from time of involvement. Equally, if not more, important than the 'how long?' is the 'how?' of involvement. Broadly, Lundy (2007) specified the 'how?' of involvement through the four elements of space, voice, audience and influence. However, the implementation is key. Activities must be designed to enable children to access information to develop informed views, they must be appropriate to the children's needs to create ZPDs for CRAG participants. The questionnaire design and content must

enable research participants to access information to develop informed views and be appropriate to the children's needs to create ZPDs for research participants. It is evident from my research that no matter how long the involvement, if the process is not carefully and appropriately designed, using the children's rights-based methodology as an enactment of CHT then the benefits will not come to fruition.

It is not possible to produce a 'step-by-step' guide to making children's rights-based methodology work. This is dependent on many factors, including the children or adult coresearchers. Had my research project been over a shorter timescale, each of the pieces/elements of Lundy's methodology would still have been in place. However, it would have been necessary to have a narrower scope for involvement than transpired over the prolonged period of my study. The longer timescale permitted us to broaden the scope and do more than I had envisaged at the outset. This was also due to the children's willingness to keep coming back to participate, and to keep pushing their own boundaries. I do not think that we would have achieved the depth and insight discussed in this thesis had I tried to, for example, hold all 10 CRAG meetings over a period of one school year.

In planning for research using the children's rights-based methodology the key focus must be on the depth of what is done; too broad a scope in too short a timescale risks the involvement becoming surface and potentially tokenistic. Too narrow a scope, limiting children's involvement, has the same effect. In terms of logistics, these risks also exist. For example, asking a school to identify at short notice, children who could participate in a CRAG might lead to involvement of children chosen by teachers, whom teachers perceive as: likely to be interested; likely to return the consent forms from parents timeously; not having other complicating factors which might 'disrupt' the research; tending to have consistent school attendance so unlikely to miss any CRAG meetings. The adult coresearchers may feel the pressure of 'making this CRAG work' and whilst expressing the voluntary nature of participation, may operate CRAG meetings more like a typical teacher-pupil relationship under pressure to 'get it done' or 'make it work'. Within my study, I could be relaxed about the timeline for: building the relationships with and between the CRAG participants; involving a university student to bridge and mediate these relationships; accessing information to assist development of informed voice through activities and visits outside school.

There was an inevitably long lead-in time when working with the CRAG participants outside the school to arrange availability of all involved and logistics such as risk assessment and transport. I had the privilege of being able to very carefully plan the activities for each of the 10 meetings, for discussion with my supervisor, colleagues in Ireland and Scotland, and with the originators of the methodology, Lundy and McEvoy. These aspects all contributed to the depth of the experience and should not be sacrificed in a shorter timescale if the benefits are to become evident for all involved and for the research.

As I write this thesis, I am embarking upon work engaging qualified secondary STEM teachers in Scotland as a Student Research Advisory Group (SRAG). These teachers have undertaken a route to become fully-registered teachers comprising 36 weeks of initial teacher education (ITE) within a higher education institution followed by the 40-week GTCS Teacher Induction Scheme (TIS) based in a school. I am implementing a model based on the methodology used within my doctoral research to develop a research instrument for use with current students undertaking an innovative model of teacher education, unique in Scotland to the University of Dundee. The model combines the ITE and TIS stages over a 52-week course. The timescales for working with the SRAG will be shorter than in my doctoral research. Elsewhere in this thesis (see for example, *Learning science beyond school* in chapter two and *Do children like learning science in school?* in chapter five) I have identified examples of where retrospective and contemporary evaluations paint very different pictures of experiences. Hence there is a need to complete this piece of work whilst the students are current, rather than once they have successfully completed, or otherwise. Many of the elements of the rights-based methodology are more easily dealt with, for example ethical approval, informed consent and logistics. The design of the questionnaire may be less complex and require fewer iterations. To a larger extent than in my doctoral research, there will be examination of the lived experience of those in the SRAG, perhaps requiring less assistance in the development of informed voice. The SRAG's audience and influence is immediately evident, as is the audience and influence of the students as research participants. The time available will therefore be more focussed on ensuring that the assistance to develop informed voice is appropriate for the research participants. The outcomes of that piece of research will further inform understanding of the 'limits' of working with the rights-based methodology.

Within my doctoral research, the importance of the children's rights-based methodology is evident. In my research study, I have done something which is rare in social science research. Rather than using an existing research instrument and repeating with different cohorts (see, for example, Farmer et al., 2006; Finlayson & Roach, 2007; Schreiner & Sjoberg, 2004; Sjoberg & Schreiner, 2010), I have worked with children as coresearchers to develop a completely new instrument for research informed by children. I have discussed some elements of this in chapter four with respect to the benefits for participants. In chapter five, I discuss further the findings of the research in relation to science learning beyond the teacher-led, and the benefits of having used a children's rights-based methodology in this study.

Chapter 5 Findings and Discussion: challenge and enjoyment

Curriculum for Excellence is underpinned by seven principles of curriculum design, one of which is “challenge and enjoyment” (SG, 2008, p. 5) described thus:

Young people should find their learning challenging, engaging and motivating. The curriculum should encourage high aspirations and ambitions for all. At all stages, learners of all aptitudes and abilities should experience an appropriate level of challenge, to enable each individual to achieve his or her potential. They should be active in their learning and have opportunities to develop and demonstrate their creativity. There should be support to enable young people to sustain their effort.

(SE, Scottish Executive, 2004b, p. 14)

As with each of the principles of curriculum design, the meaning of ‘challenge and enjoyment’ is not explored within curriculum documentation (Priestley & Humes, 2010). With the learner at the centre of the curriculum, what are **children’s** aspirations for challenge and enjoyment in their science learning? And to what extent are these being achieved?

Neuroscience suggests that children can like, or enjoy, something in the moment without necessarily being stimulated or motivated to want to do more (Hobbiss, 2017). Within CfE, ‘challenge and enjoyment’ could be considered as a recognition that “pleasure and enjoyment are not sufficient conditions for intrinsic motivation” (Kim, 2013, p. 4) and that learning experiences and interactions, whilst being enjoyable at the time, should also include challenge through which children are motivated to repeat or extend their science learning.

In this chapter, I explore what children said about whether they like learning science in school. This study does not attempt to compare children’s perceptions of school science with science experiences beyond the teacher-led. However, understanding children’s feelings about science learning in school is a useful starting point which gives context to their thinking about science experiences. I also examine correlations

between liking learning science in school and enjoyment of science experiences, exploring who is having science experiences and with whom.

I discuss children's aspiration for science experiences and the reality of their science experiences. In doing so I focus on:

- whether science experiences are, or should be, fun and how research participants express the role of fun in science experiences;
- interactivity and experiments;
- 'enjoying together', the human element of interaction;
- science experiences as more than 'just a nice day out'.

In this chapter I present two latent constructs which underlie children's perceptions of and aspirations for science experiences beyond the teacher-led: internal and external motivators. I explore alignment between the extent to which children experience these in science learning beyond the teacher-led and their perceptions of their abilities in science and how much they like learning science in school.

Do children like learning science in school?

Overwhelmingly, participants responding to the research instrument in my study reported that they like learning science in school (Table 5.1), with no significant difference between the percentage of participants in primary school and in secondary school.

Table 5.1 Percentage of participants who reported that they like learning science in school

	Primary	Secondary	Significance
% of participants who responded positively to question "do you like learning science in school?"	92 (n = 482)	91 (n = 462)	not significant

Participants were offered a choice of responses: "yes – a lot"; "yes – a little"; "no". A comparison of means shows no difference in the 'strength' of positive responses in the primary and secondary sectors (Table 5.2).

Table 5.2 Comparison of means calculated from responses to question on liking learning science in school

	Primary (n = 524)	Secondary (n = 506)	Significance
Mean value calculated using SPSS independent samples t-test, including all non-blank responses	3.25	3.20	not significant

Similarly, there is no difference in the ‘strength’ of responses between male and female participants, except at age 13 (Appendix 26). Whilst almost all participating 13-year olds participants reported liking science in school, a comparison of means reveals a stronger positive response from males than female at this age, with the difference in means significant. Thirteen is also the only age at which there was a difference in the mean number of science activities enjoyed by male and female participants (Table 5.3). I could not explore whether or not this was the case for fourteen-year-olds due to the very small number of research participants aged 14.

Table 5.3 Gender breakdown of mean number of science activities enjoyed at age 13

	Female (n = 105)	Male (n = 135)	Significance
Mean value calculated using SPSS independent samples t-test	2.13	2.50	*

Thus, it appears that at age 13, a gender difference in liking of learning science in school and perhaps more broadly of science opens up for the participants in my research. This aligns with findings of the United Nations Educational, Scientific and Cultural Organisation (UNESCO) report into girls’ and women’s STEM education (UNESCO, 2017).

In 2013, a national review of science in Scotland (ES, 2013b) identified that in sciences in primary school, children are not always experiencing progression and coherence in their learning in sciences (ES, 2013b). In discussion about science in Scotland’s primary schools, between schools and at a national level, there exists a common narrative about science in primary schools among those not directly involved in teaching in primary schools: “children in primary schools do not know they are doing science”. Contrary to this, in my research, fewer than 1% (n = 4) of primary-school participants indicate that

they are “not really sure what science we do in school”. Broadly then, this paints a positive picture of science within CfE. Children participating in my research know they are doing science in school and like learning science in school.

In exploring the extent to which children in primary and secondary schools like learning science in school, the children’s rights-based methodology, and researching in the Scottish context is important. My findings align with those of a 2017 report for the Wellcome Trust (Leonardi, Lamb, Howe, & Choudhury, 2017). This Wellcome Trust study intended to establish a baseline for research on primary science in the UK including Scotland, although only 3%¹⁷ of pupil respondents were located in Scotland. Leonardi et al. (2017) report that 85% of children like science at school either a lot or a little, and 87% find it interesting. My findings, and those of Leonardi et al. (2017), contradict previous research carried out in Scotland. An extension to the *ROSE* survey in Scotland for pupils in the third year of secondary education concluded that “pupil responses regarding primary school science were quite negative” and identified “quite strong” and “very strong” disagreement with the statements “I found science at primary school interesting” and “science at primary school prepared me well for science in secondary school” (Farmer et al., 2006, p. 36). In Farmer et al. (2006), all groups agreed with the statement “I find science at secondary school more interesting than science in primary school”, with agreement ranging from mild to very strong depending on whether respondents were studying biology only, or all three discrete sciences (biology, chemistry and physics). Statistical information is not available within the published report to explore further these statements.

The study carried out by Farmer et al. (2006) was completed prior to the development and implementation of CfE. Might there have been a change in children’s liking of learning science in school since CfE was implemented in schools? Aligning with my study, the findings of the 2003 Assessment and Achievement Programme (AAP) survey of science in Scotland (SE, 2005a), carried out prior to development of CfE, do not support the idea that primary children have overwhelmingly negative views of science in primary schools. Within the AAP study, the vast majority of respondents in primary

¹⁷ n = 53

5 and primary 7 indicated that science topics are “always” or “mostly” interesting with fewer secondary-school participants agreeing this was the case.¹⁸

Arguably, the problematic methodology employed by Farmer et al. (2006) damages the legitimacy of the conclusions drawn, which conflict with the broad range of research in the field and with other research carried out in Scotland. Farmer et al. (2006) required children to respond to over 250 questions, recalling and rating experiences from at least two to three school years earlier. In a 2013 Wellcome Trust report tracking public views on science, biomedical research and science education (Wellcome Trust, 2013), 83% of respondents aged 14-18 report increased interest in science in secondary compared with primary school. Again, these young people are giving views of experiences from several years earlier. The alignment of this aspect of these two retrospective studies, and the conflict with other research in the field, highlights that how experiences of primary science are viewed with hindsight or how teenagers recall their childhood experiences, is not representative of views captured at the time of the experience (A. Bell, 2007). This is particularly an issue if policy and curriculum decisions are based on these retrospective views, or the narrative from retrospective research permeates the conversations about science in schools as it does in Scotland. The Scottish science education community is small. There is overlap and crossover between those involved with such research, with learned societies and with groups established to advise Scottish Government on science and STEM in education, and the initial and continuing development of CfE. As Humes (2013) describes it, there is a “traditional patronage model used to control entry to the Scottish policy community...a well-established system of recruitment for public service in Scotland” (p. 16).

The *ROSE* survey was adapted for further use in Scotland in 2007, with primary-school aged pupils (Finlayson & Roach, 2007). The final report connects responses to the statement “I like science better than most other subjects” with “strongly negative” (p. 33) responses found by Farmer et al. (2006) among pupils in the third year of secondary school. There is no criticality applied to the use of Farmer et al. (2006). No justification is offered as to why there should be a need for children to like science more than most

¹⁸ 87% (n = 433) of primary 5 and 83% (n = 362) of primary 7 respondents indicated that science topics are “always” or “mostly” interesting, compared with 77% (n = 259) of pupils in the second year of secondary school.

other subjects. Despite a majority of children expressing the view that they find science interesting, Finlayson and Roach (2007) identify children's failure to agree that they like science better than most other subjects, as a negative response. Any ranking system is open to the risk of introducing a negative perspective through the interpretation of the researcher. A child who is very positively disposed to science but who likes other subjects more, will be categorised as having responded negatively, whilst a child who feels negatively about science but less so than other subjects may be recorded as responding positively (Osborne, Simon, & Collins, 2003).

In each of the surveys discussed in this section, children's 'liking' of science can only be inferred from other questions. It is therefore open to researchers' interpretations and bias. For children, liking science may be different from liking **learning** science. In my study, children were asked directly whether they like learning science in school, in language framed by 'people like them' (Murphy et al., 2013). In my research, CRAG participants identified that it was important to know whether participants like learning science in school. They did not feel it was necessary to know whether science is participants' favourite subject or how much they like science compared to other subjects. Similarly, children participating in a study by Murphy et al. (2010), a large-scale study (n = 1000) for Wellcome Trust using a children's rights-based methodology, identified that failure to name science as the favourite subject should not be interpreted as a negative response. This is a clear example of how the use of a children's rights-based methodology to involve children as coresearchers in all stages of the research, influences the research to reduce interpretation by adult coresearchers, and allows us to better understand children's thinking. It allows for the development of new and innovative research instruments, rather than simply adapting and repeating what has been done before as in the case of the studies carried out by Finlayson et al. (2007) and Farmer et al. (2006). The results of these studies aligned perhaps because the same flaws existed in the methodology and approaches to data analysis and evaluation.

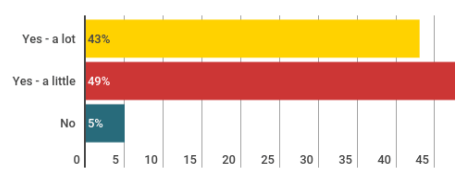
Initially, the CRAG participants anticipated that there would be differences in gender with more girls saying they like learning science a little, and more boys reporting that they like science a lot. At the beginning of their discussion on gender, CRAG participants suggested that 50% of boys and only 25% of girls would say that they like learning science "a lot". However, as the discussion progressed, the CRAG participants

suggested two factors which may influence responses: girls might be influenced by their friends' responses to a greater extent than boys; boys may choose "yes – a little" to avoid appearing to be a "goodie-two-shoes". They also discussed the conflicting view that participants might feel obliged to give the 'right answer' and respond positively with "yes – a lot". It was evident that the CRAG participants understand other children's responses to quantitative questions as being complex, influenced by a number of factors, and therefore open to interpretation. The CRAG anticipated that collecting data from children in their first year of secondary school would reveal that more children in first year than in primary school would like science, with a decline thereafter.

The CRAG participants considered responses to "do you like learning science in school?" presented in the form of a chart, and were asked questions developed from those used by Murphy et al. (2010) (Figure 5.1). Seeking clarification of the age range of participants, the CRAG participants reiterated that they anticipated an increase in positive responses among those who had experienced first year in secondary school. The CRAG participants perceived greater variety in science in first year of secondary school; their indication that primary seven included repetition of work they had done before aligns with the findings of Murphy and Beggs (2003) in their exploration of attitudes to science in primary school. It should be noted that this is by no means inevitable. Work by Murphy, Beggs, Carlisle, and Greenwood (2004) indicates the strength of coteaching with qualified primary teachers and pre-service teachers of science subjects for increasing enjoyment of science lessons including among girls in topics in physical sciences such as electricity and energy.

The CRAG sought clarification on the expected responses including: whether participants could select more than one response to this question; whether the total of responses should add up to 100%; whether the 3% not accounted for within the bar chart were those who selected the "I'm not really sure what science we do in school" response.

Do you like learning science in school?



What do you think of the children's answers?

Is there anything about this that surprises you? Why does it surprise you?

Is there anything which doesn't surprise you? Why is that?

Is there anything you would like to know more about?

Figure 5.1 Prompt questions for CRAG discussion of questionnaire data, as presented to the CRAG participants

Having considered the responses, the CRAG participants again discussed a conflict between wanting to align answers with those given by friends, and not wanting to be a “teacher’s pet”. In general, the CRAG participants were not surprised by the responses, describing the data using words such as “normal” and phrases such as “what I thought would happen”. However, one comment was “I thought less would say no”.

The CRAG participants provided insight into the research methodology when discussing participants’ liking of learning science. They were not surprised that the majority of participants reported that they like learning science in school; their first-hand experiences lead them to believe that children in primary school like learning science. However, they noted that although every effort was made not to convey obligation, some participants may have perceived the questionnaire as a test and felt obliged to be positive in their responses. This is a crucial aspect for consideration when undertaking research involving children. Arguably, this sense of obligation will influence the responses to any research questionnaires used with children in schools, including the *Programme for International Student Assessment (PISA)* (OECD, 2018) and *ROSE* surveys. The deliberate strategy to minimise the sense of obligation in my research, contrasts with much research in which the sense of obligation is deliberately conveyed and those not completing the whole questionnaire have their answers disregarded (see

for example, Farmer et al, 2006; Strange et al., 2003). It is reasonable to assume that the sense of obligation identified by the CRAG as a potential issue might also affect feedback on out-of-school science experiences, where feedback is requested from children at the end of the experience or visit, in the presence of the staff from the experience and in the visit location. Rather than attempting to identify explanations and solutions, the methodology of some research studies leads to the issues being problematised (Bennett & Hogarth, 2009); a children's rights-based approach with children as coresearchers brings a new perspective and informs us about children's views and experiences of learning science within CfE.

Those who like learning science in school...

Within my study, liking learning science in school correlated most strongly with reporting being good at science, and with finding science experiences beyond those that are teacher-led, fun and interesting (Appendix 20). Correlations between liking learning science in school and enjoyment of science activities, such as visiting places to do with science, although very highly significant, are only weakly positive. However, those who reported that they like learning science in school, also reported enjoyment of more science activities such as watching science TV, visiting places to do with science and nature walks than those who do not like learning science in school (Table 5.4).

Table 5.4 Mean number of science activities enjoyed by those who do and do not like learning science in school

	Like learning science in school (n = 944)	Do not like learning science in school (n = 78)	Significance
Mean number of science activities enjoyed ¹⁹	2.52	1.38	***

For those who like learning science in school, their experiences in school may also be providing the stimulus and motivation to want to do more, and they feel positively about science experiences with which they engage, finding them fun and interesting. All participants who used the words "like" or "love" to describe how science experiences make them feel about science reported that they like learning science in

¹⁹ value calculated using SPSS independent samples t-test

school “a little” or “a lot”. Those who like learning science in school “a lot” account for the majority of uses (71%, n= 39). Either those who like learning science in school consequently enjoy science experiences, or those who enjoy science experiences consequently like learning science in school.

In contrast, none of those who do not like learning science in school report that science experiences make them like or love science. Only around one-third of this group find science experiences fun (31%) or interesting (33%). Compared with those who like learning science in school, a smaller proportion of those who do not like learning science in school report positive feelings about science as a result of science experiences (Table 5.5). Such participants are not experiencing, as a result of learning science in school, a motivation to extend their science experience beyond the teacher-led. Science experiences beyond the teacher-led with which they do engage are not encouraging positive feelings about science. In my research, an important finding is that those who reported negative feelings about science learning beyond that which is teacher-led do not necessarily dislike learning science in school, with 9% liking learning science in school “a lot” and 57% “a little”.

Table 5.5 Participants who reported positive feelings about science

	All participants (n = 1043)		Participants who reported that they do not like science in school (n = 78)		Participants who reported that they like learning science in school (n = 944)	
	n	%	n	%	n	%
Participants who reported that science experiences make them feel positively about science	581	56	10	13	571	60
Significance comparing with full sample (excluding those in relevant subgroup)				***		***
Significance comparing participants who do not like learning science in school with those who like learning science in school						***

Who is having science experiences, and with whom?

Eighty-five percent of participants reported experiencing science learning beyond the teacher-led, either solely with their school or both with school and with family or friends. Four in ten participants' science experiences are only with school, whilst fewer than 1 in 6 participants have only experienced out-of-school science with friends or family (Table 5.6).

Examining the responses for the full sample obscures wide variation between responses from primary and secondary-school participants. More participants in secondary school than primary school reported having science experiences with their school (Table 5.7). This could reflect the city location of one of the secondary schools and easier access to science experiences, compared with small town or rurality of many of the participating primary schools.

Table 5.6 Primary-secondary sector breakdown of science experiences with school, with family or friends only, both with school and with family or friends

	Participants responding to this question (n = 1024)					
	Primary and secondary		Primary only		Secondary only	
	n	%	n	%	n	%
With school only	432	42	156	30	276	55
With family or friends only	152	15	120	23	32	6
Both with school and with family or friends	440	43	247	47	193	39
With school only OR both with school and with family or friends	872	85	403	77	469	94

Table 5.7 Primary-secondary sector breakdown of science experiences with school

	Primary only		Secondary only		Significance
	n	%	n	%	
With school only OR both with school and with family or friends	403	77	469	94	***

Despite greater exposure to science experiences with school, participants in secondary schools reported enjoying fewer science activities than participants in primary schools (Table 5.8). Far fewer secondary-school than primary-school participants reported having science experiences with family and friends, either exclusively or in addition to experiences with their schools (Table 5.9). Greater exposure to science experiences, with schools post-primary, is not motivating children in the study to participate in more science activities beyond the teacher-led. This could be due to competing demands on the time of children as they progress in to secondary school, or alternative activities which become available as they grow up.

Table 5.8 Primary-secondary sector breakdown of mean number of science activities enjoyed

	Participants in primary schools (n = 532)	Participants in secondary schools (n = 511)	Significance
Mean number of science activities enjoyed ²⁰	2.53	2.29	**

Table 5.9 Primary-secondary sector breakdown of science experiences with family or friends

	Primary only		Secondary only		Significance
	n	%	n	%	
With family or friends only	120	23	32	6	***
Both with school and with family or friends	247	47	193	39	**
With family or friends only OR both with school and with family or friends	367	70	225	45	***

Regardless of feelings about liking learning science or how good participants perceive their science abilities to be, there is no grouping more likely than another to have been exposed to science experiences solely with family and friends. Exposure to science

²⁰ value calculated using SPSS independent samples t-test

experiences solely with family and friends is not significantly different between those who report that they like learning science in school “a lot”, those who do not like learning science in school, those who report that they are “very good” or “not good” at science, nor between male and female participants. This makes sense in a primary setting where science experiences are likely to involve a whole class, and in the early years of secondary before children might choose to opt out of sciences. In these age groups, if one in the participating class has had science experiences with school, it is likely that all within that class or year group will have had these same experiences. It would therefore be unlikely to find that, at the same time, one sub-group has more exposure solely with family or friends. This is a useful aspect to explore in that it suggests validity in the question.

However, examining exposure to science experiences **only** with school, there are highly significant differences between those who identified that they are not good at science, and those who reported liking learning science in school “a lot”, and between each of these groups and the full sample (Table 5.10).

Table 5.10 Science experiences with school only

	All participants (n = 1024)		Participants who reported that they are not good at science (n = 91)		Participants who reported that they like learning science “a lot” (n = 399)	
	n	%	n	%	n	%
With school only	432	42	57	63	129	32
Significance comparing with full sample (excluding those in relevant subgroup)			***		***	
Significance comparing participants who identified as “not good” at science, with those who like learning science “a lot”					***	

For those who feel that they are not good at science there is perhaps a lack of confidence in engaging with science experiences beyond the teacher-led, hence far more of these participants have science experiences **only** with their school. The CRAG participants were not surprised by the number of respondents, approximately 3 in 10 in the initial data-collection phase, who had not had a science experience with family or friends. Despite the vast majority of participants having reported that they like learning science in school (> 92%), it made sense to the CRAG participants that some people may not like science enough to do it outside school. They likened this to not liking art enough to go to art galleries, with one member of the CRAG saying, “I would never go to a maths museum!”.

Children’s aspirations and the reality of their experiences

Participants in my research study know they are learning science and like learning science in school. Many also enjoy science activities (Table 5.11), although participants in secondary schools enjoy fewer science activities than participants in primary schools (Table 5.8). Taken as a ranking, those in secondary schools enjoy the same activities as do those in primary schools. The opportunity to do experiments is the activity most frequently selected by participants. This enjoyment of experiments accords with the findings of Pell and Jarvis (2001) in their work on developing scales to measure children’s attitudes to science.

Table 5.11 Primary-secondary sector breakdown of science activities enjoyed

Science activity enjoyed	Full sample n =	%	Primary %	Secondary %	Significance of difference between primary and secondary
doing experiments with science kits	792	76	75	77	not significant
visiting places to do with science	568	55	62	47	***
watching science TV programmes	551	53	55	51	not significant
nature walks	400	38	40	37	not significant
reading science magazines	120	12	13	10	*

As children progress from primary to secondary school, there is no decline in the reported liking of learning science. Enjoyment of doing science experiments continues. However, for both male and female participants, there is a highly significant difference in enjoyment of visiting places to do with science (Table 5.12). Fewer participants in secondary than primary school enjoy visiting places to do with science.

Table 5.12 Primary-secondary sector and gender breakdown of enjoyment of visiting places to do with science

Participants who reported enjoyment of visiting places to do with science	Primary n	%	Secondary n	%	Significance of difference between primary and secondary
Female	171	66	111	48	***
Male	157	58	125	46	**

This decline coincides with fewer secondary-school participants than primary-school participants reporting that their science experiences were fun and interesting (Table 5.13) and a weak negative correlation between finding science experiences fun and the age of the participant.

Table 5.13 Primary-secondary sector breakdown of finding science experiences fun and interesting

Participants who reported that science experiences were	Primary %	Secondary %	Significance of difference between primary and secondary
fun	83	73	***
interesting	79	73	**

The decline in enjoyment of visiting places to do with science and in finding science experiences fun and interesting may not be related to a decline in liking learning science or a decline in interest in science itself. CRAG participants suggested the decrease in the proportion of children reporting enjoyment of visiting places to do with science, and reporting finding science experiences fun and interesting might be to do with a combination of factors. The first is having “seen it before”; CRAG participants felt that places they have visited to do with science do not update displays and activities or keep up-to-date. The second is their perception that places to do with science are aimed at, and designed to be more fun for, younger children.

That fewer participants in secondary schools than primary schools enjoy visiting places to do with science may also be explained by findings of research into science attitudes. Haladyna et al. (1982) identify a clear correlation between science attitudes and the quality of teaching for children in grades 7 and 9 in schools in the USA, equivalent to the first and third years of secondary school in Scotland. This correlation is not evident for younger children (Haladyna et al., 1982). Thus, for children in early secondary school, their attitude to science, and their enjoyment of science experiences and places to do with science, may be linked to the quality of teaching. This may be because at this age, children change their perceptions or definitions of 'quality of teaching', or because they become more discerning based on their wider experiences (Haladyna et al., 1982). The quality of teaching described by Haladyna et al. (1982) and Haladyna, Olsen, and Shaughnessy (1983) incorporates the teacher's commitment to helping children learn and their support for individuals, respect for the teacher's knowledge, use of praise and reinforcement, and fairness. The approaches used in science experiences beyond those which are teacher-led may not be meeting the needs of the age group as children progress from primary to secondary school, nor delivering on the expectations they have formed from their school and wider experiences.

In developing the research instrument, the CRAG participants' view was that science experiences should help learning. They suggested an explanation for fewer secondary-school participants finding science experiences fun or interesting. The CRAG proposed that more participants in secondary schools would find their science experience 'educational' and thus fewer would report it as 'fun'. This is a really important insight from the CRAG, the anticipation of a distinction between primary and secondary-school participants science experiences, with those for secondary-school participants being more educational, less about fun and more about learning. It is interesting that they group a drop in 'interest' with this, suggesting that the CRAG participants do not necessarily agree that something must be 'interesting' for learning to take place.

Aspects of research participants' experiences which I identified as being 'educational' are the extent to which the experience: made it easy to learn; made participants think; increased participants' curiosity. Examining these aspects, the proportions of participants agreeing that their science experiences made it easy for them to learn and

made them think, was not significantly different between primary and secondary school (Table 5.14). There was a significant difference between the proportion of primary and secondary participants who agreed that their science experiences increased their curiosity. However, fewer secondary-school than primary-school participants agreed with this statement. On this basis, the idea that children in secondary school are finding science experiences more educational and hence less fun is not borne out by the data. Whilst fewer find it fun or interesting, there is not a concomitant increase in ‘educational’ aspects.

Table 5.14 Primary-secondary sector breakdown of indicators of finding science experiences ‘educational’

Participants who reported that science experiences	Primary		Secondary		Significance of difference between primary and secondary
	n	%	n	%	
made it easy for them to learn	284	56	255	53	not significant
made them think	344	68	311	64	not significant
increased their curiosity	294	59	252	51	*

There is a correlation between reporting that science experiences made it easy to learn and liking learning science in school and, less strongly, with positive perception of science ability (Appendix 20). In terms of learning, science experiences are more valuable for those who like learning science and feel they are good at science, and less so for those who do not. Agreeing that “my science experience made it easy for me to learn” is most strongly correlated with reporting that it is fun, interesting and increases understanding of the wider world (Appendix 20). This correlation between learning and fun, mirroring the aspiration of CfE to incorporate and connect “challenge and enjoyment” in learning, is one which I explore in greater depth in the next section, beginning with an exploration of participants’ perceptions of fun and enjoyment.

Enjoyment...is it fun?

More than three-quarters of participants in my research²¹ report finding their science experiences fun. Fun features in the responses of 170 participants about how science

²¹ 78%, n = 818

experiences make them feel about science²². In some cases, the word “fun”²³ is used positively within an otherwise negative response, for example:

“It gets boring at times but sometimes is fun, very rarely though.”

(participant, age 12, secondary school);

or in a way which reveal the individual’s perception of fun; a visit can be fun without being interesting or always enjoyable:

“Going to places like Dynamic Earth is fun, but I'm not really interested in it. I enjoy it sometimes but not always.”

(participant, age 13, secondary school).

Whilst the majority of participants report finding their science experiences fun, responses to open-ended questions indicate that they do not consequently believe that science ‘is fun’. Does fun feature in participants’ aspirations for their learning through, and enjoyment of, science experiences? The word “fun” features in relation to how science experiences can help children enjoy science experiences and learn from science experiences (Table 5.15). However, it does not feature to the extent that common narrative might suggest; children are not overwhelmingly identifying “fun” as a factor in learning or enjoying science. For more than 80% of participants, fun does not appear to be a factor in their enjoyment or learning.

Table 5.15 Responses to open-ended questions featuring the word “fun”

Question	Number of responses featuring word “fun”	% of responses featuring word “fun”
How can science experiences help you learn?	99	12
How can science experiences help you enjoy science more?	134	16

²² 18% of 933 responses

²³ The word funner was also included, this is a not uncommon expression for ‘more fun’ in the geographical area in which the field work was undertaken.

To explore these responses further, NVivo word clouds of these responses were created (Figure 5.2²⁴ and Figure 5.3²⁴). Figure 5.2 is a word cloud of the 150 unique words appearing in the 99 responses from primary-school and secondary-school participants to the question “how can science experiences help you learn?” featuring the word fun.

Figure 5.2 NVivo created cloud of words ($n = 150$ unique words) appearing in responses to “how can science experiences help you learn?” which include the word fun

Figure 5.3 NVivo created cloud of words ($n = 190$ unique words) appearing in responses to “how can science experiences help you enjoy science?” which include the word fun

For participants in my research, through this visual analysis a connection emerges between learning, perceptions of fun, and interaction with experiments. This connection is more evident in more detailed analysis of the use of the words “learn”, “experiments” and “interactive”, which appear frequently within responses which include the word “fun”. Where children were asked to suggest what science experiences could do to help them **enjoy** science more, the most commonly used words in responses which feature the word “fun” are “experiment” and “learn”. Csikszentmihalyi (2002) identifies and defines a difference between enjoyment and pleasure, the latter being a passive experience and the former one of active engagement, and “direct participation by the individual” (Jones, 1998, p. 206). For participants in my study, the connection between perceptions of fun, ‘direct participation’ including interaction and experiments, and learning, is explored in the next section.

Enjoying interaction

Interactivity emerges strongly as a theme from participants’ responses to the questionnaire (Table 5.16). Interactivity, that which Csikszentmihalyi (2002) would consider the active engagement which leads to enjoyment, emerges in relation to experiments, technologies and doing, “rather than just sitting and watching” (participant, age 13, secondary school).

Table 5.16 Responses to open-ended questions featuring interactivity and participation

Question	Number of responses featuring interactivity and participation	% of responses featuring interactivity and participation
How can science experiences help you learn? (n = 830)	363	44
How can science experiences help you enjoy science more? (n = 804)	454	56
Significance of difference between proportions		***

Many participants want “direct participation” (Jones, 1998, p. 206). To help them to enjoy science experiences more and to help them learn from science experience, they want to **do**, rather than watch, experiments and to work independently, with opportunities to create experiments. The following indicative quotes illustrate this across the age range and sectors sampled:

“I would like it if there was more experiments that I could do, and less that the staff do”

(participant, age 9, primary school);

“instead of listening all the time you should do the experiments”

(participant, age 12, secondary school);

“I think we should be able to have some time to try out the experiments we were shown and make up our own to understand how they work”

(participant, age 10, primary school);

“you could be free to actually ‘experiment’ instead of be told what to do”

(participant, age 13, secondary school).

Some participants do refer to experiments without also expressing a desire for greater interactivity to help increase learning through science experiences and enjoyment of these experiences (Table 5.17). However, far more responses referring to experiments relate to wanting to do, create or carry out experiments or express the desire for greater interactivity in science experiences.

Table 5.17 Responses to open-ended questions relating to experiments

	% of responses relating to “experiments”	
	without interactivity	with interactivity
How can science experiences help you learn? (n = 830)	7 (n = 58)	14 (n = 116)
How can science experiences help you enjoy science more? (n = 804)	7 (n = 53)	18 (n = 145)
Significance of difference between proportions	not significant	*

The vast majority of those who talk positively about experiments, talk about doing them and interacting with them. In participants’ discussion of how science experiences make them feel about science, the opportunity to **do** experiments and be hands-on features in the majority (88%) of positive responses about experiments. This finding from the perspective of children as research participants, aligns with a recommendation of a 2009 review by the National Research Council that informal environments for learning science should be interactive (P. Bell et al., 2009). However, the children’s rights-based methodology gives greater insight into the meaning of interactivity for children, being hands-on and ‘doing science’, not simply watching science shows or using technologies.

The desire for interactivity and its connection with fun which emerges from participants’ responses accords with Gray’s (2010) proposition that fun aligns more closely with work than with entertainment. Participants are not seeking to simply be entertained. However, getting hands-on with experiments is not necessarily the answer to increase enjoyment or learning for all. Of those reporting negative feelings about science experiences²⁵, only 8% report positive feelings about doing experiments, and fewer than 20% and 12% respectively refer to doing experiments in terms of increasing their learning through or enjoyment of science experiences. Far fewer participants who feel they are not good at science enjoy doing science experiments with kits compared with those who report that they are OK or very good at science (Table 5.18).

²⁵ n = 77

Table 5.18 Enjoyment of doing experiments with kits by perception of science ability

	% of participants who report their science abilities as		
	not good	OK	very good
Reporting enjoyment of doing science experiments with kits	58 (n = 53)	77 (n = 560)	84 (n = 179)
Significance of difference between not good and OK		***	
Significance of difference between not good and very good			***

Caution must be exercised before assuming that interactivity and doing experiments creates a positive experience. The difference in the proportions of those who enjoy visiting places to do with science depending on their perceptions of how good they are at science may also tie in with this (Table 5.19). Far fewer of those who perceive that they are not good at science reporting enjoyment of visiting places to do with science compared to those who are OK and very good.

Table 5.19 Enjoyment of visiting places to do with science by perception of science ability

	% of participants who report their science abilities as		
	not good	OK	very good
Reporting enjoyment of visiting places to do with science	37 (n = 34)	55 (n = 398)	64 (n = 136)
Significance of difference between not good and OK		**	
Significance of difference between not good and very good			***

Visiting places, getting hands-on, and interactivity, may make those who perceive themselves as “not good” at science feel exposed, more so than watching science TV and reading science magazines. For watching science TV and reading science magazines, there is no difference in the proportion of those who are “not good” at science reporting enjoyment, compared with the full sample. That far fewer of those who have negative perceptions of their science experiences report positive feelings about *doing* experiment is an important issue and area which would benefit from further research. It is contrary to what schools might consider as an approach to engage those who have negative feelings about their abilities in science. To help them engage with and enjoy science more, schools might well attempt to increase hands-on experimental work. It is a common assumption that ‘getting hands-on’ is a key part of what children look for in science learning. However, it should perhaps be borne in mind that there are fields of theoretical and computational sciences which are less emphasised, and which might appeal more to some.

The notion of interactivity underpinning children’s enjoyment of science and science experiences, and learning through science experiences, does not relate solely to hands-on experiments. Children use a wide range of language to describe activities and interactions that would them to enjoy science more as a result of science experiences. Encompassed in this is the idea of ‘being included’, although this is more evident in responses relating to enjoyment, rather than learning, of science. For example:

“I think science experiences should include everyone young or old, and staff need to be kind and helpful even it’s a silly question”

(participant, age 13, secondary school);

“I think everyone should have the chance to do the same things. Not just a person do something and everybody watches”

(participant, age 11, primary school);

“make sure to involve everyone. This way, everyone would be focused and enjoy it more”

(participant, age 14, secondary school).

The desire for experiences to incorporate challenge, also emerges from the responses about interactivity, for example:

“I would like to have a go myself and interact and be asked more questions”

(participant, age 11, primary school);

“ask us questions about what they are talking about”

(participant, age 9, primary school);

“we should spend time on the computers doing research and games”

(participant, age 12, secondary school).

Included as interactivity are responses about ‘games’. Statements about games feature in responses from primary-school and secondary-school participants, in relation to enjoyment and learning. Some are very clearly about active involvement by the participants, for example:

“you should be able to play science games”

(participant, age 10, primary school);

“I think it would be fun to do science games”

(participant, age 13, secondary school).

In other responses the element of active involvement is more implicit, for example:

“I would enjoy it more if there was informative games”

(participant, age 13, secondary school).

Through exploration with colleagues, I have interpreted that the nature of games is such that they incorporate interaction and activity. The consensus among colleagues was that in the cultural context of children in Scotland, “games” implies taking part and doing; it would not be reasonable to interpret this as children wanting to watch others play games. This contrasts with the treatment of the responses including the words “experiment” and “experiments” which do not in themselves imply active involvement.

Children may well have experienced science shows and demonstrations of experiments at science centres, festivals or in school. Thus, phrases which do not explicitly call for 'doing' experiments or active involvement cannot be assumed to imply interaction, whilst the use of the word "games" is taken to imply participation, interaction and 'doing'. I did not have the opportunity to discuss this with the CRAG. However, I explored this with the child who had scripted and filmed the introductory video for participants when she was aged 10-11. She has had a range of experiences of science in school and out of school, including visits to science centres with family and friends, and with schools. The discussion with her, aged 14, is captured in the following extract:

Researcher: If I ask, "what can science experiences do to help you enjoy science more" and they say, "more games" what does that mean?

Girl: More things like interactive games where you play out the scenarios and stuff. Or like the light game at Dundee. Not like at Edinburgh where they say it's interactive but it's just clicking through things.

Researcher: Can you think of an example where people might say they want more games and mean something other than for them to do?

Girl: No, I can't think so. Glasgow is good, it's interactive. Just that Glasgow has like the Bodyworks thing and all that, it just...yeah.

Researcher: Can you think of where children might want games, for them to watch, not do?

Girl: No, that is THE most boring thing on Earth. (*rolls eyes*)

This conversation informed my thinking on the interpretation of references to games to imply active involvement. It also highlighted that responses might relate to computer games and apps as well as or instead of games in a traditional sense. Colleagues reviewing the complete data set, also identified 'technologies' as a notable theme. Technologies, including references to "tech", "gadgets", "apps", "computer games", and "iPads", feature much more frequently within responses as a tool for interactivity to increase enjoyment of science experiences rather than to enable learning (Table 5.20), for example:

"I would like to have apps on the app store for more fun";

(participant, age 10, primary school);

“let us use modern technology more because kids find it more fun”;
(participant, age 13, secondary school).

Table 5.20 Responses to open-ended questions relating to technologies

Question	% of responses relating to access to or use of “technologies”
How can science experiences help you learn? (n = 830)	3 (n = 25)
How can science experiences help you enjoy science more? (n = 804)	7 (n = 60)

Against this aspiration, more than half of participants agree that their science experiences gave them the opportunity to use modern technologies (Appendix 27). The use of technologies as a tool for increasing interactivity, and indeed children’s understanding of the meaning of “modern” technologies, would be an area for further exploration in relation to enjoyment of science experiences.

Many participants’ responses in relation to enjoyment of science experiences and learning through science experiences (Table 5.16) indicate that children do not want a passive experience; this is not just about pleasure. These participants want interactivity, activity, participation, and the opportunity to do, use and work with sciences and technologies, either individually or with others. They want to be active through exploring, discovering, finding out and developing understanding. The responses are illustrated through NVivo-generated word clouds of the words which appear most frequently in responses coded as ‘interactivity’ relating to learning (Figure 5.4) and enjoyment (Figure 5.5). In each case, the responses from primary-school and secondary-school participants are included.



Figure 5.4 NVivo created cloud of most frequent words appearing in responses (n = 369) to “how can science experiences help you learn?” relating to interactivity



Figure 5.5 NVivo created cloud of most frequent words appearing in responses (n = 454) to “how can science experiences help you enjoy science more?” relating to interactivity

In a cultural-historical context, opportunities for interaction are opportunities for learning and development. Vygotsky argued that there exists an “inherent relationship between external and internal activity” (Wertsch & Stone, 1985, p. 163). Through interaction, children can become involved in activities more complex than those which

they can manage alone and such external process of practical activity can transform into internal processes (Wertsch & Stone, 1985). There is arguably a connection between the desire for greater interactivity and accessing greater challenge; through this social learning comes development of higher psychological functions.

Enjoying together

My research is underpinned by CHT in which human interaction mediates the development of internalised higher psychological functions (Chaiklin, 2003). From participants' responses, there emerges a demand for interaction to aid learning and enjoyment of science. Hence, it is of interest to explore what participants say with respect to the 'social aspects' of science experiences, and the extent to which they consider others' needs and perspectives beyond their own. There are 225 responses relating to learning through and enjoyment of science experiences which explicitly or implicitly refer to working, talking or learning together, identify group activities or talk about more than their individual wants and needs. The following indicative quotes illustrate this aspect of responses:

"do the experiment with your teacher and then do the same thing with a friend"

(participant, age 10, primary school);

"help other people to learn things"

(participant, age 9, primary school);

"I would enjoy it when we talk more about science"

(participant, age 10, primary school);

"spend time with your friends while learning"

(participant, age 12, secondary school).

That participants are thinking about others' needs, and considering 'people like them' (Murphy et al., 2013) emerges from these responses, illustrated in the following indicative quotes:

“to let us have a chance of learning ourselves. As the results would be from us. Some people would rather do their own research”

(participant, age 11, primary school);

“they should dedicate more time to explaining things, and allow more free-choice for pupils”

(participant, age 14, secondary school);

“we should be allowed to be more independent and learn at our own pace”

(participant, age 12, secondary school).

Such responses also serve to illustrate a sense that comes through in the questionnaire responses, that participants are seeking an element of choice and independence. Science experiences may not always be ‘free-choice’ in Falk’s (2001) definition of the term. However, within such experiences, many children are seeking opportunity for learning independently with choice and control. Gray (2010) proposes that in the school setting, “fun” has the following characteristics: “it is collective; it is reciprocal; it is interactive; it involves control (possibly collective control) rather than loss of control; it is equitable; it should not have a downside (e.g. future punishment, work time to be made up)” (p. 129). It is perhaps the case that these characteristics of fun equally apply to science learning beyond the teacher-led, and indeed children may have come to expect an element of choice and control through their experiences at school, underpinned by “personalisation and choice” as one of the principles of the design of CfE (SG, 2008, p. 5).

Is everyone enjoying themselves?

Unsurprisingly, some children report that science experiences make them feel negatively about science. Negative sentiments feature in 8%²⁶ of the non-blank responses about how science experiences make them feel about science. Some of the responses include only negative statements, for example:

²⁶ n = 77

“it makes me feel like I don't want a job to do with science”

(participant, age 11, primary school);

“it makes me feel bored, even the thought of it does”

(participant, age 12, secondary school);

“it makes me feel like I have nothing better to do because I don't understand it”

(participant, age 12, secondary school).

Within other responses, negative sentiments are mixed in with less negative or more positive sentiments:

“I feel confused a bit because sometimes it's too complicated to understand but sometimes I want to know more.”

(participant, age 10, primary school);

“it makes me feel more informed about nature, but it also makes me feel like I don't want to do science next year.”

(participant, age 13, secondary school).

There is no significant difference in the proportion of negative responses when comparing genders. However, there is a difference, highly significant at the $p = 0.01$ level, between the sectors. More secondary-school participants report negative feelings than primary-school participants. This again may suggest that secondary-school participants' needs are not being met by science experiences with which they engage (see also *Children's aspirations and the reality of their experiences* in chapter five).

Negative responses to questions from those who do not like learning science in school are perhaps unsurprising. However, the responses of participants in my research illustrate that children who do not like learning science in school are not necessarily being 'switched on' to science by science centres and visits. There is also a link between negative perception of science ability and negative feelings about science experiences.

Far fewer participants who perceive that they are not good at science find science experiences fun and interesting, compared with participants who perceive they are very good or “OK” at science (Table 5.21) with differences very highly significant.

Table 5.21 Finding science experiences fun and interesting by perception of science ability

Agreement with statement “my science experience was...”	Participants’ perception of science ability						Significance of differences between		
	Not good (n = 91)		OK (n = 730)		Very good (n = 214)		Not good and OK	OK and very good	Not good and very good
	n	%	n	%	n	%			
fun ²⁷	41	47	588	83	185	89	***	*	***
interesting ²⁷	39	47	555	80	194	92	***	***	***

A quarter of those reporting that they are not good at science share negative feelings about science experiences in their responses, although this group make up only 7% of all respondents to the question relating to feelings about science experiences. And whilst only 9% of research participants report that they are not good at science, 29% of those reporting negative feelings about science experiences feel that they are not good at science.

For those who report negative feelings about their science experiences, those who do not like learning science in school and those who perceive that they are not good at science, fun does not feature significantly in what they **want** from science experiences to help them enjoy science more or learn from science experiences. For children who have negative feelings about science, their science abilities or science experiences beyond the teacher-led, fun is not necessarily the answer. Again, this runs contrary to a common narrative (see, for example, *Informal versus formal learning debate* in chapter two) that fun is the answer to switching children on to science with the

²⁷ where no response to this statement, omitted before percentage calculation

implication that this is lacking in school science learning. It is clear from the responses from participants in my research that whilst many report science experiences as having been fun, this is not a key aspect of participants' **aspirations** for their science experiences. Those who do seek fun are using this in a way closer to the idea of enjoyment through challenge, than a pleasurable or entertaining day out.

Challenge and purpose: it matters more than just a nice day out

In my research, reporting science experiences as fun correlates most strongly with finding that such experiences made it easy to learn, were interesting, encouraged creativity and curiosity and provided opportunities to explore new things (Appendix 20). There is also moderate correlation with liking learning science in school. These correlations, along with the connections between fun, learning and interaction discussed in the previous section, suggest that the fun identified by participants is about deeper engagement and effort rather than “messaging about” (Gray, 2010, p. 125). The fun of science experiences may be that which McManus and Furnham (2010), in a large-scale study of adults' perceptions and experiences of fun, describe as “achievement” (p. 164) which correlates with focus, challenge, accomplishment, and being absorbed and engrossed. In short, this is the enjoyment which comes from challenge, rather than pleasure (Csikszentmihalyi, 2002).

A principal component analysis of participants' responses about their science experiences indicates that there are two main components to the science experiences of participants (see *Principal Component Analysis* in chapter three). One is “external motivators”: relevance, context, and the wider world. The other is “internal motivators”: fun, interest, curiosity and finding that science experiences make it easy to learn. Exploring first the internal motivators (Appendix 27), this grouping further suggests that fun as pleasure is not a main motivator. When participants talk about “fun” they are associating it with purposeful activities with identifiable outcomes (Gray, 2010), with focused activity as well as energetic excitement (McManus & Furnham, 2010). This aligns with a cultural-historical perspective; Vygotsky would suggest that play is about more than having fun, and that play and work are not “polar opposites” (Lantolf, 2003, p. 355). The extent to which participants agree that science experiences

are ‘delivering’ on the elements which contribute to internal motivation is shown in Table 5.22.

Table 5.22 Experience of ‘internal motivators’ by perception of science ability

Agreement with statement	Participants’ perception of science ability						Significance of differences between		
	Not good (n = 91)		OK (n = 730)		Very good (n = 214)		Not good and OK	OK and very good	Not good and very good
“my science experience ...”	n	%	n	%	n	%			
was fun ²⁸	41	47	588	83	85	89	***	*	***
was interesting ²⁸	39	47	555	80	194	92	***	***	***
increased curiosity ²⁸	20	24	378	54	146	71	***	***	***
made it easy to learn ²⁸	19	23	373	54	146	71	***	***	***

Far fewer participants who perceive that they are not good at science report experiencing each the four elements of the ‘internal motivators’, compared with those who feel that they are OK or very good at science. Thus, those who perceive themselves as not being good at science, do not experience the combination of factors which may lead to internal motivation for more science learning as a result of science experiences. One of the elements of flow theory (Csikszentmihalyi, 2002) is “deep but effortless involvement (losing awareness of worry and frustration of everyday activity)” (Jones, 1998, p. 206). For those who do not perceive themselves as being good at science, experiences involving science may not allow for this state to be achieved. Science experiences may in fact introduce worry and frustration for those who lack confidence in their science abilities. Without the opportunity to “concentrate and interact with the opportunities at a level commensurate with one’s skills” (Csikszentmihalyi, 2002, p. 119), without a relationship between the “activity and the individual’s goals” (Draper, 1999, p. 118) there is a failure to create ZPDs for these participants. My research

²⁸ where no response to this statement, omitted before percentage calculation

suggests that science experiences are not creating ZPDs for those who perceive their science abilities negatively.

Responses to open-ended questions (Table 5.23) illustrate that many participants feel that science experiences should be about more than novelty and entertainment, incorporating challenge and purpose, thinking and access to information, particularly to help children learn.

Table 5.23 Responses to open-ended questions relating to challenge and purpose

Question	% of responses relating to challenge and purpose
How do science experiences make you feel about science? (n = 933)	33 (n = 311)
How can science experiences help you learn? (n = 830)	31 (n = 258)
How can science experiences help you enjoy science more? (n = 804)	19 (n = 150)

The need to learn and develop understanding emerges, illustrated in these indicative quotes:

“I would learn more with more challenging work”

(participant, age 11, primary school);

“There should be information that kids can read and make more sense so that it’s easier to understand”

(participant, age 10, primary school).

The connection between enjoyment and learning, emerges both in participants’ suggestions about how to help them learn more from science experiences, and how to help them enjoy science more, for example:

“it would be good if in science centres there were books and diagrams to understand because if you are just told you don't understand”

(participant, age 10, primary school);

“I think there should be more colour pictures and drawings to learn more about science”

(participant, age 11, primary school);

“it would make me enjoy it more if the staff knew more about it and could explain it to you in a fun, interactive way”

(participant, age 12, secondary school).

Where participants' responses indicate that science experiences have motivated them²⁹, 45% of these participants refer to learning and a further 14% to knowing, connecting learning and motivation. Fewer than 8% of these responses connect motivation to having fun.

Within the body of responses (Table 5.23) which indicate that children want more from their science experiences than entertainment, that they feel that such experiences should matter and have challenge and purpose, there are two sub-themes: learning, thinking and developing understanding; and taking a broader perspective and futures. The first sub-theme broadly aligns with the identified 'internal motivators', and the latter with the 'external motivators' of relevance, context, and the wider world.

The external motivators map closely to aspects of CfE including: relevance, one of the principles of curriculum design (SG, 2008); the drive to develop in learners the attributes of responsible citizens with a developed knowledge of Scotland's place in the world and the ability to evaluate environmental, scientific and technological issues (SG, 2009); the attributes of scientifically literate citizens (LTS, 2009). The following quotes illustrate examples of participants' aspirations aligning with these aspects of CfE:

²⁹ n = 148

“they make me feel like there's a lot more to the world than I thought
and expands my brain to wider things”

(participant, age 11, primary school);

“it makes me excited, it makes me feel smarter and I think will help me
grow up, science is a great thing, and everyone should take part. Science
can help the world and help people make technology, science we need it
to survive.”

(participant, age 11, primary school);

“experiments make me understand science more and makes me think
about the impact science has”

(participant, age 13, secondary school).

The ‘external motivators’ suggest that where science experiences help participants to understand Scotland and its place in the world, to think about environmental, technological and scientific issues, and increase understanding of the world around them, they also help them to understand the relevance of science and make them think about jobs and careers in science. This aligns with children’s aspirations for science experiences to be about ‘broader perspectives and futures’.

The ‘jobs and futures’ aspect of the ‘broader perspectives and futures’ subtheme was identified through the detailed analysis of the full sample data, including working with colleagues as described in *Coding data in NVivo 11 and inter-rater reliability* in chapter three. It is also a theme which was identified by CRAG participants reviewing responses to the phase I data from primary-school children. There is a connection between how much participants like learning science and responses relating to ‘futures’ (Table 5.24).

The extent to which research participants discuss aspirations for their futures and jobs is no different between: those who do not like learning science in school and those who like it “a little”; those who do not like learning science in school and those who like it a lot. And yet, for many research participants their science experiences are not providing

the element of ‘external motivators’. The ‘external motivators’ include developing understanding of the relevance of science in their own contexts and considering jobs and careers in science.

Table 5.24 Participants’ liking of learning science in school and their science experiences (futures and jobs)

	All participants (n = 1043)		Participants who reported that they...							
			do not like learning science in school (n = 78)		like learning science in school “a little” (n = 545)		like learning science in school “a lot” (n = 399)			
	n	%	n	%	n	%	n	%		
Participants discussing how they feel about science in terms of futures and jobs	57	5	2	3	18	3	37	9		
Significance comparing “do not like” with “like a little”					not significant					
like “a little” and “a lot”									***	
do not like and “a lot”									not significant	

Far more of those who perceive that they are very good at science report that through their science experiences they have had opportunities to: understand Scotland and its place in the world; think about environmental, technological and scientific issues; understand how science affects their way of living and the world around them; use modern technologies (Tables 5.25). For example, 78% of those who perceive that they are very good at science report that their science experiences showed them how science affects their way of living compared with only 42% of those who perceive their science abilities negatively. The differences are very highly significant. Table 5.25 shows that the more positively the research participants rate their science abilities, the

more they experience ‘external motivators’ as a result of science experiences. The less positively participants rate their science experiences, the less their science experiences provide opportunities for ‘external motivation’.

Table 5.25 Experience of ‘external motivators’ by perception of science ability

Agreement with statement “my science experience ...”	Participants’ perception of science ability						Significance of differences between		
	not good		OK		very good		not good and OK	OK and very good	not good and very good
	(n = 91)		(n = 730)		(n = 214)				
	n	%	n	%	n	%			
helped me to understand Scotland and its place in the world ³⁰	21	26	278	40	99	48	*	*	***
made me think about jobs ³⁰	26	31	241	35	115	57	not significant	***	***
helped me to think about environmental, technological and scientific issues ³⁰	17	20	338	49	138	67	***	***	***
showed me how science affects our way of living ³⁰	35	42	433	63	161	78	***	***	***
gave me a chance to use modern technologies ³⁰	30	37	398	58	145	72	***	***	***
increased my understanding of the world around me ³⁰	23	28	383	55	153	74	***	***	***

This picture is broadly repeated when looking at the exposure to the ‘external motivators’ in relation to the strength of participants’ liking of learning science in school

³⁰ where no response to this statement, omitted before percentage calculation

(Table 5.26). Those who strongly like learning science in school are having a different, arguably better, experience than those who are less positive, across all element of 'external motivation'.

Table 5.26 Experience of 'external motivators' by liking of learning science in school

Agreement with statement "my science experience ..."	Participants' liking of learning science in school						Significance of differences between		
	do not like (n = 78)		like a little (n = 545)		like a lot (n = 399)		do not like and like a little	like a little and a lot	do not like and like a lot
	n	%	n	%	n	%			
helped me to understand Scotland and its place in the world ³¹	17	23	193	38	182	48	*	***	***
made me think about jobs ³¹	11	15	170	34	196	52	***	***	***
helped me to think about environmental, technological and scientific issues ³¹	15	20	236	46	238	62	***	***	***
showed me how science affects our way of living ³¹	18	24	317	62	287	75	***	***	***
gave me a chance to use modern technologies ³¹	22	30	299	59	246	65	***	not significant	***
increased my understanding of the world around me ³¹	19	25	267	52	269	70	***	***	***

³¹ where no response to this statement, omitted before percentage calculation

For example, 70% of those who like learning science in school “a lot” report that science experiences increase their understanding of the world around them, compared with only 30% of those who do not like learning science in school. This is problematic if science experiences are intended to encourage a lifelong scientific literacy or to develop ‘scientific citizens’; it appears that those who perceive their science abilities negatively or do not like learning science in school are not being well-served by science experiences in this respect. It is worth noting here that far fewer of those who do not like learning science in school are experiencing the ‘internal motivators’ than those who like learning science in school a lot (Table 5.27).

Table 5.27 Experience of ‘internal motivators’ by liking of learning science in school

Agreement with statement “my science experience ...”	Participants’ liking of learning science in school						Significance of differences between		
	do not like		like a little		like a lot		do not like and like a little	like a little and a lot	do not like and like a lot
	n	%	n	%	n	%			
was fun ³²	24	32	410	77	371	95	***	***	***
was interesting ³²	26	36	392	76	362	94	***	***	***
increased curiosity ³²	14	19	249	48	274	72	***	***	***
made it easy to learn ³²	14	19	255	49	262	69	***	***	***

³² where no response to this statement, omitted before percentage calculation

There is evidence of some research participants' feeling positively motivated³³ or experiencing increased confidence³⁴ towards science as a result of science experiences, for example:

"I feel better about science and confident when I go to high school"

(participant, age 11, primary school).

"It makes me feel more interested and want to know in more detail"

(participant, age 11, primary school).

In terms of the development of increased confidence or more positive feelings about themselves as a result of science experiences, the differences between those who like and do not like learning science in school are not significant. Nor is this dependent on perceived science ability. However, far fewer research participants who report that they do not like learning science in school feel positively motivated by their science experiences, compared with those who like learning science in school a little or a lot. These differences are highly significant. This ties together with the finding fewer of those who do not like learning at school are experiencing the 'external motivators' or the 'internal motivators' and supports the notion that those who like learning science in school are positively benefitting from their science experiences and experiencing the elements which contribute to motivation. Those who do not like learning science at school are not being motivated in science by their science experiences.

Understanding science learning beyond the teacher-led through a children's rights-based methodology

The findings of my research study demonstrate that using an "an *explicit-CRC informed approach* to participation" (Lundy & McEvoy, 2011, p. 3) to explore children's perceptions and experiences of science learning produces findings which align with other published research to reassure us about the validity and reliability of the methodology of this and other research. For example, the CRAG participants framed

³³ n = 148

³⁴ n = 51

the question “do you like learning science in school?” to directly explore this with research participants, rather than inferring from other answers in a questionnaire or survey whether children like, or like learning, science.

More importantly, using a children’s rights-based methodology produces new insights and reduces the influence of research bias and the adults’ agenda on the research. For example, adult researchers in the Farmer et al. (2006) study decided on children’s intentions and thus discarded questionnaire returns, disproportionately silencing children working at lower academic levels. Finlayson and Roach (2007) identified as problematic children’s failure to report liking science more than other subjects in school. The CRAG participants, aligning with children participating in CRAGs as part of Murphy et al. (2013), did not see ranking ‘subject liking’ as important or relevant to understanding children’s experiences. The CRAG participants identified nuances in the research with ‘people like them’ (Murphy et al., 2013) and data evaluation with which would not be evident to adult researchers. For example, they identified reasons why girls and boys might answer the question “do you like learning science in school?” with “yes – a little” rather than “yes – a lot”. The reasons given, such as not wanting to seem like a “goodie two shoes”, may equally apply to children not identifying science as their ‘favourite subject’ in other research surveys. By accessing children’s informed voice, working with children as coresearchers, the risk of ‘misunderstanding’ of interpretation by adults, based on their own assumptions, is reduced.

CRAG participants understood the complexities of interpretation of data, even quantitative data in response to closed questions, and the complexities of how a research participant may decide upon an answer to select or arrive at an answer to share via a questionnaire. The CRAG participants identified the impact on the quality of data gathered of a ‘sense of obligation’ to participate, despite the best efforts within the methodology of my study to remove this. They also identified the impact on the quality of the data gathered of research participants’ self-image and peer pressure, despite the guarantees of anonymity and confidentiality. Such insight is crucial to understanding the to move forward both thinking and practice, not only in science education but across all aspects of research into learning and teaching with children. These two issues identified by the CRAG participants will arguably impact on any and all

research and evaluation involving children, whether one-off surveys relating to school visits or larger-scale research studies.

Methodologically, a children's rights-based approach can be considered more robust, evidenced in part by the completion rates of over 90% in response to the **invitation** to children to participate in the research study. The length of the questionnaire and number of questions may appear to be a simple aspect which could be identified by adult researchers. However, so often it is not. In one survey reviewed by the children (Schreiner & Sjoberg, 2004), there were over 250 questions in small black font to be answered. The need for contextualisation as part of information to assist in the development of informed views may also seem self-evident and yet it rarely features. The need for the experience of completing a survey or questionnaire to be engaging and interesting to the children through carefully thought out design and layout, including visual content created by children is also rarely considered. Working with the CRAG participants as coresearchers to better understand the perspectives of 'people like them' (Murphy et al., 2013) bridges the gap between the researcher and the researched, and thus provides more robust data.

Eighty-five percent of research participants reported experiencing science learning beyond the teacher-led. The key findings within this chapter are now summarised.

Children like learning science in school

The vast majority of children participating in this research study know they are studying science in school, and like learning science in school. The most popular 'science activity' reported by both primary-school and secondary-school research participants is 'doing experiments with science kits'. There is no difference in how positively research participants report their liking of learning science in school by sector (primary/secondary), nor by gender. The exception to this is at age 13, when male participants report a stronger liking for learning science in school compared with female participants. At this age, there is also a difference in the number of science activities enjoyed, with male participants enjoying more than female participants.

Liking learning science in school correlated most strongly with self-reported perception of being good at science, and with finding science learning beyond the teacher-led fun and interesting. Research participants who reported liking learning science in school also reported enjoyment of more science activities, such as watching television or going on nature walks, than those who do not like learning science in school.

Science learning beyond the teacher-led is not meeting the aspirations and needs of children in secondary schools

As children progress from primary to secondary school, whilst the reported liking of learning science in school does not decline, there is a decrease in enjoyment of visiting places to do with science. This decrease happens for both male and female participants although the decrease is greater for female than male participants. This decrease coincides with fewer secondary-school than primary-school participants finding science experiences fun or interesting. Reasons suggested for this decline are that:

- secondary-school participants have 'seen it before' with science experiences failing to refresh and update;
- science experiences are designed primarily for younger children;
- secondary-school participants are more discerning about 'quality of teaching' as a result of wider experiences and science experiences are not meeting their needs or expectations.

More secondary-school than primary-school participants reported negative feelings about science experiences. Research participants who reported negative feelings about science experiences do not necessarily dislike learning science in school. Around two-thirds of those reporting negative feelings about science experiences like learning science in school a little or a lot.

The CRAG participants suggested that secondary-school participants would report finding their science experiences 'more educational' than primary-school participants, accounting for the drop in secondary-school participants finding science experiences beyond the teacher-led fun or interesting. However, this was not borne out by the data. Looking at items which can be considered as relating to 'educational' nature of the science experience, there was no difference between primary-school and secondary-

school participants' experiences. An exception was that more primary-school than secondary-school participants reported that science experiences increased their curiosity.

Fun is an aspiration for only a small proportion of children

Fun does not feature as strongly as might be anticipated in children's aspirations for science experiences beyond the teacher-led. Whilst more than three-quarters of participants reported that their science experiences were fun, this did not translate to feeling that science itself is fun. Fewer than one in five participants expressed 'fun' as a factor in science experiences helping them enjoy science more (16%) or helping them learn (12%). Where 'fun' is sought, it is more closely related to the enjoyment that comes through the challenge of experimenting and learning rather than entertainment. Far more of the participants' responses relating to motivation make links to learning and knowing, rather than having fun.

Interactivity and participation is a strongly emerging theme

Much more evident is research participants' view that interactivity and participation would help them learn and enjoy science more through science experiences. Interaction, with experiments, activities, game and one another is an important theme in participants' aspirations for science experiences. For example, almost 90% of positive feelings about experiments relate to doing and interacting, rather than watching. Whilst more than half of research participants report opportunities to use 'modern technologies' through their science experiences, this does not feature highly in their aspirations for learning and enjoying science more through science experiences. Only 3% and 7% of research participants identified access to or use of 'technologies' as playing a role in helping them learn science or enjoy science more.

There are two factors underlying research participants' science experiences:

'external' and 'internal' motivators

There are two factors underlying research participants' experiences of science learning beyond the teacher-led:

- 'external motivators' which can be broadly described as relevance, context and purpose of science, including the purpose and place of science in society and relevance to own lives and careers;
- 'internal motivators', finding science experiences fun, interesting, increasing curiosity and making it easier to learn.

'Challenge and purpose' as an aspiration for science experiences

Around one-third of responses to questions about how participants' feel about science and how science experiences can help them learn, and one-fifth of responses to the question about how science experiences can help them enjoy science more, related to 'challenge and purpose'. Within these responses, two sub-themes emerged: taking a broader perspective and futures; learning, thinking and developing understanding. These themes map onto the 'external motivators' and 'internal motivators' identified as underlying research participants' science experiences. The alignment of this aspect of connecting aspiration and experience requires further exploration through future research.

The experiences of children with negative self-perceptions of science abilities

Compared with those who have more positive-self perceptions of their science abilities, fewer participants who have negative perceptions of their science abilities:

- report enjoyment of visiting places to do with science;
- find science experiences beyond the teacher-led fun and interesting, with fun not featuring significantly in their aspirations for science experiences;
- experience the elements of 'internal motivators', factors leading to internal motivation within their science experiences;
- experience the elements of 'external motivators', factors leading to external motivation within their science experiences;

More of the group who have negative perceptions of their science abilities:

- report negative feelings about science experiences. Of these less than one in ten report positive feelings about doing experiments. This, along with other aspects of the data, indicates that caution must be exercised before assuming that interactivity and doing experiments appeals to all, with particular attention paid to those who have negative perceptions of their science abilities.
- report having science experiences only with their school, compared with those with strongly positive perceptions of their science abilities.

The experiences of children with who do not like learning science in school

Of research participants who do not like learning science in school, none report that science experiences beyond the teacher-led make them like or love science; only around one-third of this group find science experiences fun or interesting. Like those who have negative perceptions of their science abilities, 'fun' does not feature strongly as an aspiration for their science experiences. Those who do not like learning science in school enjoy fewer science activities than those who like learning science in school.

The extent to which participants who do not like learning science in school discuss aspirations for futures and job in their responses is not different from those who like learning science in school "a little" or "a lot". However, fewer research participants who do not like learning in school, compared with those who do like learning in school:

- report that science experiences make them feel positively about science (13% compared with 60%);
- experience the elements of 'internal motivators', factors leading to internal motivation within their science experiences;
- experience the elements of 'external motivators', factors leading to external motivation within their science experiences.

Chapter 6 Discussion: learning science in Scotland and children's voice

Curriculum for Excellence (CfE) was envisioned as a transformation in Scottish education, through an aspirational, coherent and challenging curriculum for children aged 3 to 18 in Scotland's schools, representing "one of the most ambitious programmes of educational change ever undertaken in Scotland" (SG, 2008, p. 8). The purpose of the curriculum, encapsulated in the 'four capacities', is to enable young people to become successful learners, confident individuals, responsible citizens and effective contributors (SG, 2009). There has been debate about whether it is indeed a 'curriculum' as might be traditionally understood, about the complexities of CfE which intertwines knowledge and skills, capacities, attributes and capabilities, and about the issues of intention versus implementation (Biesta, 2008; Convery, 2017; Hedge & MacKenzie, 2016; Priestley & Minty, 2013; Wallace & Priestley, 2017). CfE might better be described as a wide-ranging set of reforms encompassing assessment, pedagogy and skills development (Bloomer, 2016) with an emphasis on teacher agency (Priestley, 2010).

The radical vision of school-based learning presented within CfE (Priestley & Miller, 2012) includes a shift in language to redefine the curriculum from what happens in school, including the subjects and the wider goals encompassed within the four capacities, to recognising the curriculum as the totality of learning wherever it happens, including opportunities for personal achievement (SG, 2008). In the context of sciences, schools are encouraged to enrich the curriculum with wider experiences through partners such as science centres (ES, 2013b). There is an emphasis not simply on *experiencing* science beyond the teacher-led but *learning* through such experiences (ES, 2013b). However, there is lack of clarity about the educational purpose; in relation to CfE Biesta (2009) identified this as "an unproblematised acceptance that learning is good, and a failure to address education questions such as 'what are we learning?' and 'why are we learning it?'" (Priestley & Biesta, 2013, p. 5). These are important questions to address if informal learning providers are to play a role in CfE.

The development and implementation of CfE coincided with an increasing global interest in opportunities for learning beyond the school environment (Werquin, 2010). Whilst school might still be considered the main place for learning (Bybee, 2001; Osborne & Dillon, 2007), increasingly there has been recognition of the connection between learning ‘informally’ and formal education (Werquin, 2010). It seems appropriate and timeous that ambitious change in the Scottish education system should recognise learning beyond that which is teacher-led. Indeed the OECD in its review of Scottish school education, noted connectedness as a feature of CfE arising from “drawing schooling, learning in the community, and out-of-school life in general more closely together” (OECD, 2015b, p. 42).

Scotland was the first nation within the UK to legislate for children’s right to have a voice in decisions relating to their education which significantly affect them (Tisdall, 2013). CfE was envisaged by the Scottish Government as having a key role to play in realising the ambition of ensuring that all children understand and are able to exercise their rights (SG, 2011). A series of policies and curriculum guidance documentation places the ‘learner at the centre’ (see, for example, SG, 2008; SG, 2018a). However, children are rarely even recognised as having a role to play in decision-making about decisions which impact on them (Tisdall, 2013). Examining one of the four ‘capacities’ of CfE, ‘effective contributors’, Tisdall (2013) suggests that progress has not been made in engaging learners with exercising their rights in relation to learning. Establishment of pupil councils and other such structures might most positively be described as ‘symbolic’ and less so as merely ‘tokenistic’ (Tisdall, 2013). Arguably a box-ticking approach to the involvement of children (Kellett, 2009) persists.

Concern about the uptake of STEM subjects among school children for, among other reasons, economic wellbeing and development is not limited to Scotland (OECD, 2015a; DeWitt et al., 2016; DeWitt, Archer, & Osborne, 2014; Franz-Odenaal, Blotnicky, French, & Joy, 2016). Different stakeholders have different reasons for these concerns (DeWitt et al., 2016). For example, as I write this thesis, debate continues in Scotland (Scottish Parliament Education and Skills Committee, 2017) and internationally, specifically in relation to the lack of STEM graduates choosing to enter the teaching profession, with the consequent potential for negative impact on children’s experiences

of STEM learning and on the uptake of these subjects (American Physical Society, 2017; McLeish, 2017).

Despite the ambition of Scottish Government with respect to children's rights in relation to learning, the *UNCRC* and Scottish legislative framework, the recently published *STEM Education and Training Strategy for Scotland* (SG, 2017c) (hereafter referred to as 'the *STEM Strategy*') does not seek or include the views of children and young people. The mechanisms proposed for identifying evidence gaps in "understanding factors affecting choices made by young people...", and "understanding...university applicants for STEM courses", are data related focussing on interrogation of databases (SG, 2017c, p. 28). Individuals are viewed as a resource in a "STEM skills pipeline" from which there is leakage (SG, 2017c, p. 28). A conference to discuss the next steps in 'widening participation, improving delivery and meeting the needs of business' (*Agenda*, 2018) following the publication of the *STEM Strategy* (SG, 2017c) makes no mention of involving or seeking the views of children.

The absence of involvement of views of children illustrates a lack of joined-up thinking, of understanding or perhaps of real commitment to children's rights and the learner at the centre. Ironically, 2018 is the Year of Young People in Scotland (SG, 2018c). Is this an example of where adults act as gatekeepers and despite a commitment to children's rights, exclude them from matters deemed too complex (Fielding, 2004)? Strategies such as the *STEM Strategy* (SG, 2017c) are intended to impact on learners and learning. To this end, they lead to expenditure of public money. For example, following this most recent report, £2.65 million was awarded to Scotland's science centres to subsidise travel by school children to science centres, to target those under-represented in science engagement activities, and to play a role in professional learning for practitioners working in early learning and childcare settings (SG, 2017c; Somerville MSP, 2017). And yet, there is no evidence that they have sought to understand the perspectives of those at the heart of these decisions, either school children or those under-represented in science engagement activities.

The children's rights-based methodology implemented in my research study reveals that in striving for involvement of external partners in science learning as part of CfE, we may in fact be overlooking those who have negative self-perception of their science

abilities and who do not like learning science in school. By excluding children from decisions about their learning, and using exclusive and tokenistic systems of children's voice, we may also exclude from science learning groups of children in our schools.

We need experts...did we ask the children?

A scepticism about a children's rights-based approach persists although Franklin (2002) argues that from an intellectual perspective, in the UK such approaches have achieved "a degree of respectability [i]nstead of being dismissed as 'utopian nonsense' or 'mere' political correctness" (p. 3). However, a criticism levelled at the enactment of children's rights through placing children at the centre of decisions which affect their learning is that it risks encouraging a generation of narcissists who believe that they can have whatever they demand. Research suggests that narcissism levels are indeed on the increase among young people in 'Western' cultures (Brummelman et al., 2015). A large-scale study carried out in the USA identified significant increases in narcissistic tendencies among college students between the period 1982 and 2008 (Twenge & Foster, 2010). The development of narcissistic traits is not well understood (Brummelman et al., 2015). Popular media lays the blame for increasing narcissism among 'millennials' on the rise of social media (Davenport, Bergman, Bergman, & Fearrington, 2014). However, Brummelman et al. (2015) identify a connection between narcissism and parental overvaluation, whilst self-esteem is predicted by parental warmth. Parental overvaluation, seeing the child as more entitled, more special and more important than other children, leads children to internalize this belief and consequently feel they should be privileged over others (Brummelman et al., 2015; Thomaes, Bushman, Orobio de Castro, & Stegge, 2009). Parental warmth on the other hand, "affection, appreciation and positive affect...[and] enjoyment of their child" (Brummelman et al., 2015, p. 3659) is linked to high self-esteem which in turn links to empathetic tendencies rather than narcissistic ones.

It is an interesting proposition then that enacting children's legal rights through involving children in decisions which affect them may lead to narcissism. The *STEM Strategy Reference Group* who advised on the aims, priorities, specific actions and measures of success within the *STEM Strategy* (SG, 2017c) included members such as

the CEO of one of Scotland's four science centres. The membership of the group was described thus: "while members will be drawn from establishments across the education and skills system, their involvement should be based on their experiences and views" (SG, 2017e para. 3). Children in the Scottish education system could equally meet this description and provide insight and perspective which is unlikely to emerge from those involved in the provision of the system and dependent on funding. Within this thesis, there is evidence of children's ability to play a key role in policy making through access to information to develop informed voice and meaningful participation in the processes. There is also evidence that much would remain unknown without the perspective of children, for example, the expectation of science experiences being more 'educational' than 'fun'.

Can including children in matters which affect them be considered as 'overvaluation' (Brummelman et al., 2015) which may lead to narcissism? Should this also be a concern for the adults involved in such processes? Indeed, are the people who become involved in leadership, advisory and expert groups likely to already demonstrate narcissistic tendencies associated with positions of power and influence (Brunell et al., 2008; O'Reilly, Doerr, Caldwell, & Chatman, 2014)? For example, explorations of the link between narcissism and participation in 'volunteering' activities indicate a link between greater feelings of entitlement and volunteering to participate for future individual success rather than to help others (Brunell, Tumblin, & Buelow, 2014). Narcissistic people are more likely to help in public settings; narcissism may well intensify the rewards experienced from involvements in situations which bring high status and power and narcissistic people may place less importance on participation and involvement for altruistic reasons (Konrath, Ho, & Zarins, 2016). Understanding motivations and narcissism in terms of prosocial behaviours (Konrath et al., 2016) is a complex and developing field within psychology and social psychology; there is limited examination of narcissism and prosocial, as opposed to antisocial, behaviour in research (Konrath et al., 2016). However, what is evident is that it cannot be assumed that the current system of policy development is without flaws including as it does the voices of those from organisations which are reliant on or stand to gain from such developments. Nor can it be assumed that the introduction of children's informed voice to the process is likely to damage an 'ideal' system which is currently working well. Indeed, Kellett (2009) summarises Franklin (2002) thus "adults, who are deemed to have the necessary

experience, often make the wrong choices, but are not excluded from doing so on the same grounds” (p. 44).

From the cultural-historical perspective, the establishment of the ZPD requires “care and concern for the child’s education, welfare, and overall development...emotionally laden reciprocal relations between the learner and the instructor” (Levykh, 2008, p. 97). The children’s rights-based methodology, where the interactions convey affection, appreciation, enjoyment and positive affect of the adult coresearchers (Brummelman et al., 2015) may provide opportunity to develop children’s self-esteem. My experience of working with the CRAG participants was that they were not ‘demanding’. This experience aligns with research suggesting that “children readily distinguish between ‘having a say’ and ‘having their way’” (Graham & Fitzgerald, 2010, p. 347). For example, when talking about the ‘best science centre ever’ (Appendix 9) participants’ ideas and suggestions were balanced by the participants raising concerns that such ideas would be too expensive or impractical. They tempered one another’s suggestions and their own ideas thus: “it would be good if...but...” (CRAG participants, 2014). CRAG participants clearly “understood that adults were not always in a position to deliver change” (Orr et al., 2016, p. 6), a finding of a study of over 1600 children in 58 countries relating to children’s ability to exercise civil and political rights.

The activities to support the development of informed voice are designed to develop perspectives beyond those of the individual, to help children think about the needs and perspectives of ‘people like them’. Those who are narcissistic lack empathy and whilst perspective-taking or “cognitive empathy” (Maxwell & DesRoches, 2010, p. 49) is not necessarily all that is required to develop affective empathy, supported adult interventions can be used to develop empathy as a disposition (Maxwell & DesRoches, 2010). Perspective-taking, such as that encouraged by CRAG participation, is one of several “psychological mechanisms that mediate empathy” (Maxwell & DesRoches, 2010, p. 49).

Perception of social acceptance builds self-esteem (Brummelman et al., 2015). The words used by participants to describe their CRAG experience include *shared experience, team work, working with my class, friendship and bonding*. These words relate to relationships with others rather than to power, control, authority, or the ability

to make demands. This suggests that for these CRAG participants, the experience represented greater opportunity for positive building of self-esteem and empathy, than for narcissism. By working with children in the frame of children's rights and developing their understanding of their own rights, there may indeed be an opportunity for them to subsequently play a role in enacting the rights of others. Vygotsky's intention was that CHT would be a theory and a method, transforming individuals for wider societal transformation (Robbins, 2010). Using a children's rights-based methodology as an enactment of CHT, developing in children higher levels of self-esteem, perspective taking, and empathetic concern may provide such opportunity. For example, those with higher levels of self-esteem, the ability to take others' perspective and empathetic concern are less likely to exhibit bullying behaviours in the workplace (Hood, Jacobson, & Jacobson, 2017). Thus, involvement of children in research and meaningful participatory dialogue with adults, with the potential for self-discovery and self-affirmation (Graham & Fitzgerald, 2010) through the children's rights-based methodology employed in my research study may present opportunities for individual and thereafter societal improvement rather than driving an increase in narcissism.

IPSOS Mori was commissioned to undertake a survey of the STEM and language subject choices of 1781 young people in secondary schools in Scotland (SG, 2018b), published several months after the *STEM Strategy* (SG, 2017c). Like many of the surveys, questionnaires and research instruments developed to explore STEM learning for children and young people, the IPSOS Mori survey, designed by adult gatekeepers, does not include opportunities for children to voice their thinking, ideas or potential solutions. In Scotland, there is a cycle of identification of 'issues' and proposal of 'solutions' by expert groups, review groups and advisory groups (see, for example, STEMEC, 2016; Scottish Science Advisory Committee, 2003; SSAC, 2011; SEEAG, 2012). Indeed, it is acknowledged that:

we have, as a country, been here before. In 2003, the Scottish Science Advisory Committee's *Why Science Education Matters* made many recommendations similar to those made in the SEEAG Report of 2012, which we are repeating in this Report in 2016

(STEMEC, 2016, p. 5).

There is no recognition by the groups and writers of such reports, that they may themselves be part of the problem. When the recommendations of and actions arising from such strategies, reports and policies lead to no measurable impact on the matters of concern, another such process is embarked upon. Inevitably, this is entirely uninformed in process, purpose or interpretation by the perspectives of those who are experts in their own lives (Clark, 2004): children and young people. Within the STEMEC (2016) report, there is recognition of the need for an independent educational research base. However, recommendations relating to children still tend towards 'auditing' attitudes and performance rather than developing and using the informed voice of children to inform the process and outcomes. In a 2017 survey, children identified the main reasons adults do not listen to or act upon their views: "it doesn't fit with what they want to hear...they don't like their views being challenged"; "they don't think my views are important" (SG, 2018d, p. 3). Despite the aspirations, it seems that at a policy level children are not even considered as having a role to play. The methodology used successfully within my research study should be considered as an important approach if there is serious commitment to understanding children's perceptions of and aspirations for STEM education, and to shaping policy as a result.

Until now, there has not been a research-based understanding of children's experiences and perceptions of science learning developed through accessing informed voice. Children have not been asked what matters or what could be done differently in science learning, or what it is like for them. Involving children at all stages of the research, enacting articles of the *UNCRC* as advisors on 'people like them' (Murphy et al., 2013), legitimises the voice of children and provides informed voice, rather than simply having compliant children who 'say what we want to hear' to please adults (Bruck, Ceci, & Melnyk, 1997). "Children can and do engage in civic action when they are well-supported. However, they meet a range of challenges and barriers, many of which would not exist to the same extent for adults." (Orr et al., 2016, p. 8). A major strength of the methodological approach employed within my research is that it did not limit involvement to children who identified as 'suitable' by teachers or other adults, nor limit it to high achievers, 'good kids', those elected by others to participate, or those with the confidence to put themselves forward. This persists as a flaw in the system of children's participation in Scotland thus far, it is neither fair nor seen to be fair (see, for example, Sher et al, 2010a, 2010b, 2010c; Tisdall 2007, 2013), and remains by invitation

and exclusive (Tisdall, 2015). In Scotland, the risk remains of “articulate, middle-class children getting a disproportionate slice of the cake” (Kellett, 2009, p. 53) whilst our education system continues to be marred by a persistent poverty-related attainment gap, evident in early years and persisting and expanding with progression through formal school years (Sosu & Ellis, 2014). Despite intentions to enact children’s rights with respect to decisions affecting their education, systems and structures for accessing pupil voice introduced to Scotland’s schools do not appear to have had any impact upon this issue. This is perhaps unsurprising given that the structures and mechanisms for pupil voice are likely to perpetuate the status quo (Fielding, 2001c) rather than empowering children to change it (see *Learner Voice* in chapter two). The methodology employed within my research offers an approach which has now been successfully trialled in the Scottish context and could be implemented in schools to engage a wide range of learners in matters affecting learning and teaching in their own classrooms and schools, and in relation to issues at local authority level and Scotland wide. The commitment to facilitating access to information to develop the informed voice of children means that participation and an opportunity to influence and shape decision making in matters affecting their education is not limited to those children who are voted into pupil councils, considered suitable candidates by teachers, or to those who have pre-formed views from the perspective of a system which already works for them.

The children’s rights-based methodology has the potential to develop a better and deeper understanding of children’s perspectives in those responsible for decision making and those who are working in and with schools and attempting to close the attainment gap. Just as the research methodology creates ZPDs for the research and researcher, ZPDs can be created for teachers involved with ‘children’s learning advisory groups’ in school, extending their understanding of children’s perspectives and learning through the informed voice of children (Figure 6.1). In *The learner at the centre through a children’s rights-based methodology* in chapter four, I discussed some of the potential constraints in using the methodology including opportunities to work with children over an extended period of time. Schools are ideally placed for meaningful implementation of this children’s rights-based methodology, able to work with children over an extended period of time to support the development of children’s informed voice in matters which the children may otherwise not have formed a view (Lundy & McEvoy, 2011). A commitment to enabling access to information to develop informed voice

means that all and any children can be involved in issues key to learning and teaching, and in decisions which directly affect their education. Schools have the potential to implement this methodology and move beyond the tokenistic and exclusive approaches, likely to reinforce the status quo (Fielding, 2001c) currently seen in schools across Scotland (Sher et al., 2010a, 2010b, 2010c; Tisdall, 2007, 2013).

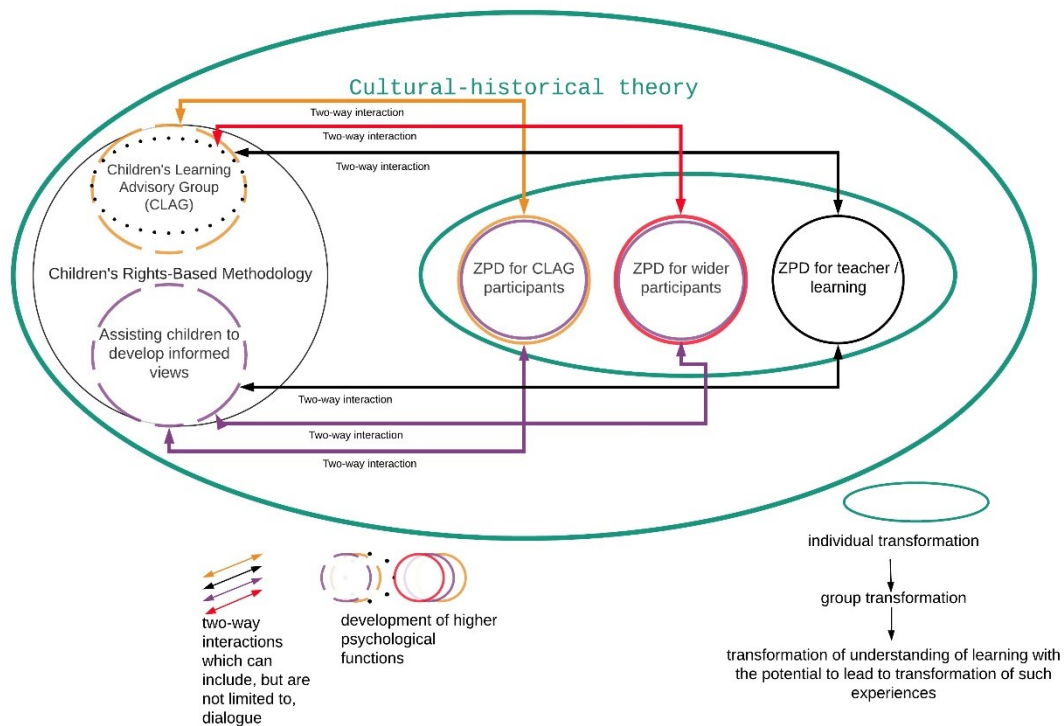


Figure 6.1 Visualisation of the creation of ZPDs through participation in a Children's Learning Advisory Group

Significant public funding is being dedicated to science and STEM learning, and to addressing the persistent poverty-relating attainment gap and disrupting the connection between deprivation, poverty and educational outcomes in the form of the Scottish Attainment Challenge and Pupil Equity Funding (SG, n.d.-a). If we as educators, politicians, teachers, or providers of science learning are serious about transformational change in education in Scotland, now is the time and opportunity to be serious about engaging children's voice. It is particularly timeous that this thesis is being written in the Year of Young People in Scotland, with the themes of engaging young people in having more say in their education and learning, and in influencing decisions that affect their lives (SG, 2018c).

Better-designed research including better-designed questionnaires (Bussey, 1995; Mellor & Moore, 2014) provides better data and therefore increased understanding to inform education policy and process. Through the rights-based methodology, response rates are improved. High-quality data are gathered which provides a perspective missing from the majority of research exploring science education in the school setting or otherwise; that of the children. When children are consulted about issues identified by adults through surveys and questionnaires designed by adults, there is not appropriate support for children to access information to understand these issues. This is something for which children themselves recognise the need (Orr et al., 2016). The children's rights-based methodology within my study was developed from the work of Lundy (2007) and Lundy and McEvoy (2011) for use over an extended period in the Scottish context, with the timescale allowing for greater support and development of informed voice. This methodology offers an opportunity to connect research which informs Scottish Government policy and action, CfE and the children who experience learning throughout Scotland. One of the architects of CfE wrote in relation to education in Scottish schools "at present there is little evidence of governments in Scotland or elsewhere looking seriously at radical long-term options" (Bloomer, 2016, p. 6). A legally-robust approach to children's rights, consulting children about their science and STEM learning and the role of wider science engagement in their learning, would fit the bill as a 'radical option' to help bring about transformational change in science and STEM learning.

Children are not all the same, and neither are their science experiences

What insight has been gained by placing learners at the centre of research, through use of the children's rights-based methodology, of children's perceptions and experiences of science experiences beyond teacher-led learning? The first insight is that there is an opportunity for informal learning providers in Scotland to challenge and address negative views they have of children's science learning in school (Falk et al., 2012). Informal learning providers should be aware and accept that children who participated in the research study as an opportunistic sample across five local authority areas,

recognise they are, and overwhelmingly like, learning science in school. There is no decline in this as children progress from primary into the first two years of secondary school. This matters. As long as informal learning providers have negative perceptions of children's views and experiences of science within formal education, it suggests that children's expectations will be low and thus gives licence to start from a low baseline in terms of what is offered to children. The strengths of informal learning will be judged and perhaps falsely inflated, against perceived failures of formal learning (Falk et al., 2012).

Accepting children's views of learning in school matters too, because it suggests that children's choice not to study sciences or pursue STEM careers may not be rooted in a dislike of learning science. Notably, there is an absence of robust or conclusive evidence to support the suggestion that greater *interest* leads to greater *attainment* in science (Nunes et al., 2017). It cannot be assumed, therefore, that an inspiring science experience which raises interest will impact on attainment. In fact, Nunes et al. (2017) identify a paradox emerging from their analysis of literature relating to science attainment and socio-economic status (SES): pupils in countries with higher science attainment have less interest in science than pupils in countries which perform relatively less well. Science experiences may strive to encourage the pursuit of careers in STEM or participation in qualifications to be able to participate in careers which encompass STEM. Ultimately, this requires attainment in STEM subjects. Rodd, Reiss, and Mujtaba (2013) identify that "fun projects or competitions" do not feature in physics undergraduates accounts of their reasons for studying physics (p. 153). The value of informal science providers efforts to make science 'fun' or 'inspiring' is perhaps questionable.

A perhaps less anticipated finding from my research is that as many children in secondary school report liking learning science and doing experiments within science kits as in primary school. However, there is a decrease in the number of children, male and female, who enjoy visiting places to do with science. Children in secondary school are also far more likely to report negative feelings about science as a result of science experiences. With the gap in science attainment growing particularly between the ages of 11 to 16 (Nunes et al., 2017), there may be a window of opportunity to focus on the design of science experiences for this age group. Such experiences could reflect what

Nunes et al. (2017) identify as three ‘cognitive mediators’ which they propose as likely to reduce the gap in science attainment between those with higher and lower SES: scientific reasoning, distinct from scientific knowledge (Bao et al., 2009); development of literacy; and metacognition. Recognising the potential for societal benefit (Hazen, 2002; Holbrook & Rannikmae, 2009; Snow & Dibner, 2016), science experiences should be shaped to offer continuing enjoyment and engagement for children and young people as they progress through secondary education, even where they may not wish to continue studying science or STEM subjects. The children’s rights-based methodology used within my research offers a way to engage children in the early years of secondary to inform and advise on practice which meets their needs.

Experiences of those who are “not good” at science

Sparkling the interest of those who perceive that they are ‘not good’ at science, may not impact on their attainment in sciences. However, if there is an intention to “ensure children, young people and adults are encouraged to develop an interest in, and enthusiasm for, STEM that is reinforced throughout their lives.” (SG, 2017c, p. 4), it should nevertheless be of concern that less than half of children who have negative perceptions of their science abilities find science experiences interesting, compared with over 90% of children who perceived themselves as ‘very good’ at science³⁵. In a recent Scottish Government report, fewer young people from SIMD 1, considered the most ‘deprived’ areas, than the least deprived SIMD 5 reported that they had chosen to study or were intending to study a STEM subject (SG, 2018b). The most common reasons given were their own negative perceptions of their ability and not being interested in STEM (SG, 2018b). Within my study, more than 60% of children who have negative perceptions of their science abilities experience science learning beyond the teacher-led only with school. Those who have negative perceptions of their science ability are not ‘missing out’ on science experiences with school but their exposure does not appear to be encouraging interest in learning science, nor motivating to undertake more science experiences beyond the teacher-led. Far fewer of them compared with those who report that they are ‘very good’ at science enjoy visiting places to do with science.

³⁵ Differences are very highly significant

A negative perception of science ability made participants far less likely to experience what were identified within my study as ‘internal motivators’: finding them fun, interesting, increasing curiosity and making it easy to learn. Those who have negative perceptions of their abilities in science are also less likely to report experiencing the ‘external motivators’ than those who report that they are very good at science. The ‘external motivators’ relate to the purpose and place of science in society, relevance to their own lives and careers. Those who report being ‘very good’ at science are far more likely than those who are ‘not good’ or ‘OK’ at science to report that their science experiences made them ‘think about jobs’³⁶.

Whilst some retrospective research has identified informal learning in science as a playing a pivotal role in the decision to study sciences in higher education (Salmi, 2003), children participating in an interactive science event with university researchers active in science research were not educated nor enthused about science careers (Illingworth et al., 2015). My research might begin to explain this apparent contradiction. The experiences children have of science centres and other science experiences varies depending on how they perceive their science abilities, or how good they are at science in school. I draw this distinction between what children report and their actual ‘science ability’ because this was a key issue identified by the CRAG; what children think and what they report may differ on setting, sense of obligation and peer influences.

There is a need for informal science learning providers to explore and understand the perceptions of science experiences of those who perceive their science ability negatively, to identify what role science experiences might play in either supporting learning or challenging these negative perceptions. Within my study, I did not attempt to examine the SES of participants. However, robust UK-wide research in over 40 years of studies, shows a link between the SES of children, their participation in science learning at school and attainment in science learning (Nunes et al., 2017). If those who report negative perceptions of their abilities in science are indeed reflecting their actual attainment, this may suggest that more of those who report negative perceptions of their ability in science are likely to be children with lower SES; an area which warrants further research.

³⁶ Differences very highly significant
230

Children's experiences of science learning beyond the teacher-led differ significantly depending on whether or not they perceive themselves to be good at science. From a cultural-historical perspective, this suggests that the science experiences are not creating ZPDs for this group of children. The body of international research relating to one-off visits to ISIs, explored within the literature review, has not established any benefit from simply getting children over the threshold of an informal science provider. This is not surprising when examined from a cultural-historical perspective. Vygotsky argued that "instruction is good only when it proceeds ahead of development, when it awakens and rouses to life those functions that are in the process of maturing" (Vygotsky, 1956, p. 278 in Wertsch & Stone, 1985). A teacher will know the learners, be more able to identify those 'functions that are in the process of maturing' and thus to create ZPDs with, in the first instance, the teacher or a peer as the MKO (Tharp & Gallimore, 1988). It would be much more challenging to do so if meeting the children only for a one-off science experience.

Creation of ZPDs requires careful planning for collaborative interaction, including planning for the important element of who will be involved (Tharp & Gallimore, 1988). Taking a science centre as an example, I suggest that the MKO (Tharp & Gallimore, 1988) presented to the children may not appear to someone who has negative perceptions of their abilities in science as a person they can 'imitate'. Science communicators are likely to be science graduates, enthused about and confident in their science knowledge, and presenting or delivering a well-rehearsed show or talk. This may present science as being out with the social context and therefore the abilities of those who do not think they are good at science, rather than as a social interaction in which the child who feels 'not good' at science can participate. Similarly, in Scottish science centres a format commonly called 'meet the expert' (Aberdeen Science Centre, 2018; DSC, 2018b; Dynamic Earth, 2018b; GSC, 2018b) is used. Scientists and engineers present on their 'specialist subject'; from a cultural-historical perspective, this is unlikely to lead to development and learning for those for whom the "buds or flowers" (Vygotsky, 1978, p. 86) are not already present. Dawson (2014) draws attention to the value placed on informal science education institutions such as museums and science centres, whilst ignoring the inaccessibility and exclusive nature of these institutions. In her exploration of the experiences of minority ethnic groups in informal science institutions in the UK,

she suggests that exclusion arises as a result of a range of practices including use of language and assumptions about prior knowledge (Dawson, 2014). Such institutions restrict rather than extend the development of science capital because what is within is accessible only to those whose own cultural capital aligns with that of the institution (Dawson, 2014; DeWitt et al., 2016).

I suggest this analysis, positing that the institutions are prepared only for the 'ideal' visitor (Dawson, 2014), could equally be explored for those children who feel they are not, or indeed are not, 'good' at science. Such children are not the 'ideal' easily able to connect with the stance and background of those leading and presenting sessions; they are therefore not benefiting from the external and internal motivators in the way that those confident in their science abilities can and do. The experiences offered by science graduates and 'experts' may reinforce rather than challenge their perceptions that careers in science are "only for the 'brainy' few" (Archer et al., 2013a, p. 14). They may reinforce that studying science equates to becoming a scientist, rather than appreciating the wide range of careers in which STEM qualifications are valuable and useful (Archer et al., 2013a). What my research demonstrates is that we can listen to and act on the advice from children about their lived experiences, people like them and issues on which they have not previously formed a view, through the use of a children's rights-based methodology. A commitment to implementing this and thus building appropriate ZPDs for the range of children who attend science centres, not only the 'ideal', may offer an opportunity for science experiences to impact on children's views of and feelings about science.

Experiences of those who do not like learning science in school

The children's rights-based methodology also provides insight relating to the experiences of those with negative perceptions of learning science in school. There is a positive relationship between those who like learning science in school and the extent of engagement with science experiences beyond the teacher-led. There is evidence that those who do not like learning science in school engage with fewer science experiences than those who like learning science in school. The relationship here is one which is worth exploring: does increased exposure to science experiences drive enjoyment of learning science in school, or does liking of learning science in school drive

motivation to visit more science experiences with family and friends? The likelihood is a complex relationship which cannot be disentangled within this study, or perhaps by further research. However, my research indicates that exposure to science experiences with school is not necessarily leading to more engagement with science activities. A far greater proportion of those who like learning science in school report positive feelings about science as a result of science experiences, compared with those who do not like learning science in school. The vast majority of those who describe how science experiences make them feel about science using the words “like” or “love” also like learning science in school “a lot”. Are those who like learning science in school predisposed to feeling that science experiences make them “like” or “love” science? Or, could a positive feeling about science, arising from science experiences, increase how much children like learning science in school? If it is the former, then science experiences risk preaching to the converted. If it is the latter, there is potentially an opportunity to impact positively on how much children like learning science in school by examining how experiences can develop positive feelings in children about science and designing experiences which do so. Within *Informal versus formal learning debate* in chapter two, I described a narrative which emerges from literature and research about informal science learning, of children feeling negatively about school-based science, whilst being enthused and inspired by science experiences. However, this was not borne out by my study. Within my study, I did not find evidence of negative feelings about learning science in school being changed by science experiences. For example, none of the children who reported that they do not like learning science in school said they ‘like’ or ‘love’ science as a result of science experiences. And children who reported negative feelings about their science experiences do not necessarily dislike learning science in school.

Reporting that they do not like learning science in school made participants far less likely to experience ‘internal motivators’ or ‘external motivators’ than those who like learning science in school. The ‘external motivators’ relate to the purpose and place of science in society, relevance to their own lives and careers.

At present, the literature in the field comes from the perspective that there is value in science experiences for increasing positive feelings, inspiring children and raising interest in science. It is assumed that the difficulty is in researching it to provide the

evidence as opposed to considering that this may not be the case. This uncritical stance is particularly evident in Scotland as discussed within the literature review. However, for the children participating in my research, the assumption does not hold. Without doubt it will be a challenging task for science experiences to engage with those who do not like learning science in school, and by impacting on how positively they feel about science, increase how much they like learning science in school. However, if science experiences funded to play a role in formal education do not accept this challenge, are they themselves drawing the conclusion that science experiences cannot impact positively on how children that do not like learning science in school feel about science? This presents a significant opportunity for research: what type of science experiences can positively impact on children's liking of learning science in school? Are science experiences likely to be able to make a difference in a way which targeted interventions in school could not? Nunes et al. (2017) draw attention to the OECD's conclusion based on PISA 2015 data that "all the correlational evidence...suggests that learning science at school may be more effective than learning science outside or after school" (OECD, 2016a, p. 227) arguing that the use of ISIs require careful and detailed planning and professional learning for the staff involved, just as is required in formal learning settings. Evidence suggests that the benefits of STEM clubs and enrichment activities in the UK are evident only for those with higher SES (Falk et al., 2012). However, exploration of the benefits or children of learning science outside the classroom with their teachers through immersive residential experiences with an 'adventure' aspect, suggests that there is potential to impact positively for those from lower SES backgrounds (Amos & Reiss, 2012). Itzek-Greulich et al. (2015) concluded that automatic benefits from science experiences cannot be assumed. I would add to this that any benefits cannot be assumed for all.

The role of informal science learning providers

Whilst working in the informal learning sector, I experienced dismissal of the idea that formal learning could offer anything to the informal sector, aligning with the findings of Falk et al. (2012) and the observations of Baram-Tsabari and Osborne (2015) that "science communicators frown at the very thought of studying science communication from an educational perspective" (p. 139). Staff were critical of teachers and schools,

and there was a common assumption that science communicators fulfil the same role as teachers for far less cost. Indeed, the idea of schools as “still imbued with the traditional deficit model and its negative connotations” (Baram-Tsabari & Osborne, 2015, p. 139) persisted and there was a failure to recognise that school-based education in Scotland has moved to a model based on constructivism and away from the ‘banking model’ of education (Freire, 2005). Science experiences continued to focus on the ‘deficit’ model of the learner (Baram-Tsabari & Osborne, 2015), which they attempted to address by presenting information and shows.

This mindset proved a barrier to the motivation to learn and improve practice in informal settings, and to understanding formal learning. That a barrier exists between the fields generally is recognised (P. Bell et al., 2009; Lewenstein, 2015). Recent research identifies the same in terms of scientists visiting schools to work with children:

“Scientists need to be aware that schools and teachers represent a profession of pedagogic and curriculum knowledge, and science communication in schools means that one professional enters the world of another...help scientists to fully appreciate the realities of daily school life, such as the status of school science...or the enormous pressures and time constraints that teachers are under: teachers have to comply with high standards expected of their teaching, the requirements ... are demanding, as is the breadth of strategies necessary to scaffold to the very different abilities across age and attainment groups”

(Patel, DeMaine, Heafield, Bianchi, & Prokop, 2017, p. 74)

Mindset may not be the only barrier. The need to use funding for learning to support the commercial aspects of the science centres inevitably leads to pressures to deliver a combination of packaged workshops and talks to high volume of children, interspersed with unsupported time on the exhibition floor. Bamberger and Tal (2007) argue that lack of knowledge of learning and teaching in the informal sector may lead to the implementation of models of completely undirected exploration, or authoritative transmission of information; in the case of Scottish science centres, the financial arrangements may also be a factor.

In the Scottish context, the unquestioning support for the work of science centres, including substantial public funding, against a backdrop of regular and frequent negative media coverage around Scotland's schools (see, for example, Denholm, 2017; MacNab, 2015, 2016) perhaps legitimises the of lack of motivation to examine and improve practice in the informal setting or to explore what it means to support children's progression in learning. From the early stages of CfE development, there was an assumption that science centres would have a role to play in the curriculum (HMIE, 2007; SEEAG, 2012). This led to a missed opportunity to examine how best science centres and other science experiences might do so, and what would be required of them to do so. The complexities of education and supporting children's learning in science (see for example, Abrahams & Reiss, 2012), the extent to which CfE raised the expectation of teachers as curriculum makers, not curriculum deliverers (Wallace & Priestley, 2017), the recognition that children do not necessarily learn what is taught and the importance of assessment during the learning process to shape and support learning to meet learners' needs (William, 2011) all suggest that a far more nuanced expertise than is typically available in science centres would be required to integrate informal science providers into the curriculum. In Scotland, teaching is a highly-skilled role requiring a minimum of two years of teacher education and probation for graduates, registration with the GTCS, an annual commitment to professional learning and a five-yearly professional registration review. The transition from entertainment which attracts and engages an audience (P. Bell et al., 2009) science communication and public engagement to supporting planned learning is undoubtedly very challenging. This challenge will surely not be overcome until there is a recognition of the necessity to do so.

In the cultural-historical perspective, the ZPD is needed to take children from one plane to another in their science learning. Vygotsky's vision was of a stage, as in a theatre, on which a child's development appears twice, on two planes; the first is the social plane and the second, the psychological plane (1983, in Veresov, 2004). These are not two different 'levels' of development but rather two points on the same stage, the two dimensions of one event (Veresov, 2005). Traditionally in science education in Scotland, one might envisage that on the stage all of the 'action' is taking place within the classroom; all that happens is within that one setting. The children may be taken to a science centre; there is a change of set and scenery. However, what chance is there

of making the connections and creating ZPDs for children when there is complete disconnect between the two settings? The challenge is to expand the stage to include both the classroom and science centres, to access this opportunity in a productive way so that the stage on which the interactions through which learning takes place and leads development is bigger. A ZPD between formal and informal learning is needed; to achieve this there must be an 'ideal' towards which to work (Chaiklin, 2003).

How can this divide between formal and informal learning be bridged, and the stage expanded? In my research, children articulated informed views of their perceptions of their science experiences and how science experiences make them feel about science, and their aspirations for how science experiences can help them learn and enjoy science more. This provides an opportunity for providers of science experiences to critically examine their role in learning based, for the first time, on children's perspectives. It may be that children perceive learning science in school as different and separate from their experiences of science and science activities beyond school. Exploration of these perceptions could form the basis for further research in this field, again employing a children's rights-based methodology. If science experiences such as science centres do seek to increase science capital by inspiring and enthusing children about science, raising interest, and raising awareness of science careers, a focus on those who self-report as "not liking" learning science in school or being "not good" at science is crucial. This is not about auditing, measuring and data gathering; through the children's rights-based methodology, children's voices can be heard and used to shape science experiences in a way which can better meet their needs and may then have greater likelihood of impact on their liking of science and liking of learning science. Applying the methodology of this research study to involving children's voice in policy development relating to STEM learning, there is an opportunity here for greater synergies to be identified, the divide bridged and the 'stage' expanded.

Research also suggests that what happens at school and at home is key to building science capital, with far less importance placed on time spent in science centres and similar places (DeWitt et al., 2016). DeWitt et al. (2016) therefore propose home and school be the focus for interventions to develop science capital. However, I suggest that this gives even greater imperative to ensuring that science experiences identify their role and how to carry it out to greatest effect. The education agenda in Scotland

is firmly focused on closing the poverty-related attainment gap (Mowat, 2018; SG, 2015c). Is it sufficient, then, for the role of science experiences to be left to assumption and chance, viewed with “ego-centrism and myopia” (Falk et al., 2015, p. 163)?

Children’s aspirations for science experiences, in the context of CfE

This thesis is titled *Children’s aspirations and perceptions of science learning beyond the teacher-led*. ‘Beyond the teacher-led’ refers the exploration of children’s experiences whether in or out of school which are not led by their normal class teacher, or teachers from within their school. What has emerged from the research is that children want science experiences to take them ‘beyond the teacher-led’, beyond that which they do in school. Whilst more than three-quarters of children responding to the research questionnaire reported finding science experiences fun, in expressing their aspirations as to how science experiences can help them learn and enjoy science, use of the word ‘fun’ is in the context of learning and interaction, interest and creativity and correlates with liking learning science in school. Aligning with “challenge and enjoyment” (SG, 2008, p. 5) one of the seven principles of curriculum design in CfE, the responses of around one-third of research participants to the questions “how do science experiences make you feel about science?” and “how can science experiences help you learn?” related to having challenge and purpose in their science experiences. Many children are not simply looking for a ‘nice day out’.

The most prominent theme emerging from the children’s responses is ‘interactivity and participation’ with many children wanting direct participation in the experiences. From a CHT perspective, this is not surprising. From a young age, children are experiencing socialisation into their family and communities, interacting in ways which “awaken and arouse mind, communication, and expression and assist the instantiation of culture and society” (Vygotsky, 1978; Werstch 1985 in Tharp & Gallimore, 1988, p. 20). In Scottish schools, children are experiencing a curriculum underpinned by constructivist views of learning (Priestley & Biesta, 2013) with roots in Vygotsky’s CHT. They are likely more familiar with working with others to construct knowledge and understanding, through interaction, than in having content delivered to them by a figure at the front. Perhaps

counterintuitively, children are not necessarily seeking interaction with technology. More than half of the participants report that science experiences gave them opportunity to use modern technologies, this does not feature strongly in responses relating to enjoyment of science and learning science.

Two factors were identified as underlying children's science experiences: external and internal motivators. The external motivators relate to relevance, context and purpose of science, including science careers. The internal motivators connect finding science experiences fun and interesting, arousing curiosity and making it easy to learn. Evidence from this study is that far more of those who hold positive perceptions of their science abilities, or who like learning science in school, report experiencing the internal and external motivators than those who have negative perceptions of their abilities or do not like learning science in school. DeWitt et al. (2016) describe science capital as "what may help transform positive attitudes and interest in science into decisions and choices – actions – that make future science participation more likely" (p. 2443). Further research could illuminate the role of the external and internal motivators in building science capital.

Chapter 7 Conclusion

This research study demonstrates that the children's rights-based methodology developed by Lundy (2007) and Lundy & McEvoy (2011) can be employed successfully for a large-scale mixed-methods study relating to mainstream learning and teaching within the curriculum, in the Scottish context. An 'insider' view (Murphy, Mullaghy & D'Arcy, 2016) leads to the content, language and design of the questionnaire being markedly different from those designed by adult researchers, resulting in high return rates and more robust data. This 'insider' view also provides insights in terms of understanding and interpreting responses, and analysing and evaluating data. Children can engage as coresearchers, about matters beyond their lived experience, and demonstrate an understanding of the nuances and challenges of research. I have identified the children's rights-based methodology employed within the research as an operationalisation of Vygotsky's CHT, through which ZPDs are created for children as coresearchers and research participants, adults as coresearchers and for research itself.

Children within the study overwhelmingly reported liking learning science in school. This is the case for research participants in primary and secondary school, with the 'gender gap' evident only in strength of responses between male and female pupils at age 13. Children who do not enjoy science learning beyond the teacher-led do not necessarily dislike learning science in school. As children progress from primary to secondary school, they continue to report liking learning science in school. However, their enjoyment of visiting places to do with science declines, as does the percentage of those reporting science experiences beyond the teacher-led as 'fun' or 'interesting'. The CRAG participants expressed an expectation that, for children in secondary school, science experiences beyond the teacher-led should be 'more educational' and 'less fun'. However, the evidence of my research is that secondary school participants are not having 'more educational' science experiences beyond the teacher-led.

Whilst the majority of participants report finding science experiences fun, they do not consequently relate this to finding science fun. Fun is not an aspiration for science experiences for the majority of research participants. To a far greater extent, children are seeking the kind of enjoyment that comes from the challenges of learning, through interactivity and participation.

Two underlying factors within children's science experiences were identified: external motivators relating to relevance, context and the wider world; internal motivators relating to fun, interest, curiosity and learning. The more positive children's self-perception of their science abilities, and the more they like learning science in school, the more likely they are to experience 'external motivators' and 'internal motivators' as a result of their science experiences beyond the teacher-led. There is a sense of science experiences beyond the teacher-led 'preaching to the converted'.

The thesis

Within this research study, my aim was to explore children's perceptions and experiences of learning science beyond the teacher-led through 'science experiences': science or science-related activities other than those which are part of structured, teacher-led learning and teaching in the school setting. In the first chapter of this thesis, I outlined the background and significance of this study. The development and implementation of CfE in Scotland coincided with a growing recognition of the potential for informal science learning to play a role in education (Stocklmayer et al., 2010). In Scotland, the redefinition of the curriculum to "include learning in and out of school and that delivered through partnerships" (ES, 2015, p. 3) was reflected in continuing and increasing support for ISIs, including the four science centres. This was in spite of a lack of evidence in Scotland or internationally of the contribution of ISIs to learning, or of their ability contribute to learning to a greater extent. Thus, my study, with an exploration and insight into children's perceptions and experiences of science experiences, has contributed to knowledge in the field.

In chapter two I discussed formal, informal, non-formal and free-choice learning, identifying some of the challenges of identifying and defining learning by intention, outcomes or setting. I explored the 'formal vs informal' debate, how informal providers perceive and position themselves, and their aspirations to inspire interest in science, encouraging STEM careers and embedding positive attitudes towards science. I revisited the Scottish context, the role of science centres since their inception in 2000 and some of the challenges faced as they seek to increase involvement in formal education. A significant gap in the research relating to science experiences is the

perspective of children. My discussion in chapter two was not limited to the benefits and challenges of involving children in research, both as coresearchers and as research participants, but rather it encompassed the wider issues of accessing children's voice. This resonates in the Scottish context. Scotland was the first of the UK nations to legislate for the right of children to have a voice in decisions relating to their education which significantly affect them (Tisdall, 2013). It is the only one of 26 countries in a study for the UN International Children's Emergency Fund (UNICEF) in which children's rights are explicitly included in initial teacher education (Jerome, Emerson, Lundy, & Orr, 2015) through the professional standards for teachers (GTCS, 2012b). CfE guidance "clearly promotes children's rights education" although it is not explicitly specified as a requirement (Jerome et al., 2015, p. 8).

Vygotsky's CHT was identified as the basis of the theoretical framework for this study, with a particular focus on ZPDs. The work of Vygotsky, in particular the ZPD, has increasingly come to the fore in science education over the past 30 years (Murphy et al., 2015). Although it is not explicitly expressed, CfE can be described as being broadly underpinned by CHT, taking a constructivist view of learning (Priestley & Biesta, 2013). In developing CHT, Vygotsky aimed to achieve a theory and method in which individual transformation could lead to wider societal transformation (Robbins, 2010). With the purpose of the curriculum being to enable young people to become successful learners, confident individuals, responsible citizens and effective contributors (SG, 2009), arguably societal transformation through individual transformation, CHT was presented as an appropriate theoretical framework for this study. In informal learning, there is a lack of theoretical underpinning (Falk et al., 2012). However there is growing consensus that CHT may be appropriate for understanding learning in information settings (Falk & Storksdieck, 2005).

Within chapter three the methodology and the adoption of interpretivist and critical theorist approaches to the study is justified. I described the adaptation and implementation of a children's rights-based methodology compliant with Article 12 of the *UNCRC* developed by Lundy (2007) and Lundy and McEvoy (2011). This involved children as coresearchers throughout the process, and children as research participants or subjects, rather than objects, demonstrating the applicability of the methodology in a large-scale, mixed-methods study. Data were gathered using questionnaires with

quantitative and open-ended questions, from 1043 children aged 8-14, in 13 primary and secondary schools across five local authorities.

In chapter four I presented the argument that the use of the children's rights-based methodology is an enactment of CHT providing structures for the creation of ZPDs for children as coresearchers, children as research participants, adult coresearchers and indeed the research, supported by the findings of my study. I offered a visualisation of this (Figure 4.19) as a new understanding of the cultural-historical theoretical underpinning to the Article 12 compliant, children's rights-based methodology developed by Lundy (2007) and Lundy and McEvoy (2011). Within the discussion in chapter six, I explored the gap between Scotland's aspiration for children's voice and the reality in STEM education, and proposed the methodology used within my research as a potential "radical option" (Bloomer, 2016, p. 6) for use at policy level, if there is a will to understand children's perceptions and experiences of science education. I proposed that this model could also be applied within schools, with 'children's learning advisory groups' formed to truly place the 'learner at the centre' and to better inform learning and teaching, moving away from the tokenistic approaches to pupil councils thus far implemented in Scotland (Sher et al., 2010a, 2010b, 2010c; Tisdall, 2007, 2013).

In chapter five, I explored what has emerged from the data as a result of placing children at the centre of the research, in relation to children's experiences and perceptions of science learning beyond the teacher-led. The data contained within this study offers insight from children's perspectives how science experiences can help them learn and enjoy science more, focussing particularly on perceptions of fun, challenge and enjoyment, and interactivity. In particular, the data offers insight into the differences in experiences of children, depending on whether they like or do not like learning science in school, and on their perceptions of their science abilities.

Chapter six brought together the theoretical underpinning and basis of the methodology of this research, CHT and children's rights, and Scotland's aspirations for CfE and as a STEM nation (SG, 2017a) with the understanding of children's science experiences beyond the teacher-led emerging from this research.

Limitations and opportunities

This study was not designed to offer generalisability. The identification of the children who participated in the CRAG and the schools through which questionnaires were distributed was opportunistic. Children from 13 schools across five local authorities participated, chosen primarily for their geographical convenience. It must be recognised that children's voice is not fixed or static, but constructed and co-constructed, "constrained and shaped by multiple factors" (Spyrou, 2011, p. 152) so the study represents a snapshot of the participants' experiences and perceptions. As I have discussed elsewhere within the thesis, I made every attempt to address issues around the power imbalance between me and the CRAG participants. However, it would be foolish to imagine that this did not still exist. Thus, all of the interactions must be viewed with this in mind. Similarly, whilst every effort has been made to remove the sense of obligation of research participants, the insight of the CRAG tells us that nevertheless, such a sense may remain, and additionally that responses are likely to be influenced by self-perception, and children's views about the perceptions of peers.

Within the thesis, I have discussed at length and evidenced through findings the advantages of using the children's rights-based methodology, and in particular involving a CRAG over more than two years to participate in all aspects of the research. In *The 'learner at the centre' through a children's rights-based methodology* in chapter four I have discussed some of the potential limitations on work of this kind. The timescale involved in research with a children's rights-based methodology is a challenge. The benefits for research and robustness of data of working with children as coresearchers are evidenced within this thesis. However, the relatively long lead-in time to engage in research involving children, and the need to work with the CRAG for more than two years to achieve these beneficial outcomes may limit its use. I have proposed a mechanism through which the benefits of the children's rights-based methodology arise (see *The 'learner at the centre' through a children's rights-based methodology* in chapter four), placing it firmly as an enactment of Vygotsky's CHT. I suggest that there may be a 'minimum' level of interaction ensuring compliance with Article 12 (Lundy, 2007) through which the benefits may still be achieved.

Identifying and engaging children to participate in the CRAG, and as research participants, is likely to present a challenge for researchers. My study involved just under 1100 children including those in the CRAG, the pilot phase and research participants. The process of undertaking research on this scale as a sole researcher was lengthy. I did not experience particular difficulties engaging schools through which to distribute the invitation to participate, primarily due to professional networks arising as a result of my background as a teacher and more broadly within science education. Nevertheless, of 31 schools approached, only 13 responded positively or within the timescales to progress the research and I imagine that were schools to be contacted 'cold' to participate in research, there may be a far lower response rate. The very high return rates in response to the invitation to participate were a direct consequence of the CRAG's involvement as coresearchers and the guidance of another child in scripting, producing and editing a video invitation for children as research participants. Fewer schools responding and low return rates in response to the invitation to participate could certainly have significantly impacted the size of sample. In embarking upon such a piece of work it is helpful to have discussions with the local authorities and relevant Head Teachers; where this work aligns with their development and improvement planning it is perhaps more likely that the research will be supported.

A challenge of working with this children's rights-based methodology is that 'one size' will not fit all. For example, it would not be appropriate to attempt to use the same questionnaire and tools developed by children aged 8 or 9 for developing the informed voice of research participants with 16 or 17-year olds. There is evidence, for example, of the older children in the sample engaging less with the views of 'some children' shared via the questionnaire. This may seem self-evident. However, it is the norm for adults to design research instruments, and to attempt to speak to and for, children of all ages. Undoubtedly, in the search for better data and more robust methodology, there must be real commitment to identifying the research participants and working with 'people like them' as coresearchers.

The personal journey to and through doctoral research

This PhD represents, or is, the culmination of my working life to date in education in Scotland. I joined higher education in the late 1990s, just as the widening access agenda was coming to the fore. Working in three higher education institutions where there was a focus on widening access, gave me an insight into the extent to which actions are taken by well-meaning, well-educated people thinking of what to 'do' about the 'problems' faced by others, the typical deficit model of those who do not seem to aspire or achieve in the way the 'well-educated' expect. As I continued my career in physics and science teaching in both the independent and state sectors in Scotland, working with organisations and associations who intend to improve and enhance science education, this way of working continued to be evident. It might best be described as a worldview from the perspective of the 'successful' white, middle class, who dominate Scottish science education (see, for example, emerging research reported by Hepburn, 2018).

As a classroom teacher my experiences of the implementation of CfE, and those of my colleagues and the children with whom I worked, were markedly different from much of the negative narrative around CfE. As I worked at a national level, it became clear that discussions which influenced policy and implementation included a limited range of views and perspectives. The extent to which there was an agenda around privileging some subjects over others and valuing those who do STEM over and above those whose talents and interests might lie elsewhere became evident. For example, there were repeated calls to give preferential treatment to candidates for primary teaching with STEM qualifications, to require STEM qualifications for entry to primary teaching, and to introduce policy to prioritise timetabling to encourage children to take all three sciences simultaneously. I do not recall mention of children, much less seeking or including the perspectives of children, in discussion relating to science and STEM education by those who sought to influence the curriculum, assessment and Scottish Government policy. Indeed, much discussion was in relation to science in the secondary school was about 'making' children study certain subjects regardless of their strengths, needs and wishes. In my time with Learning & Teaching Scotland and its reincarnation within Education Scotland, I observed the same, relatively small number of people of similar backgrounds and educations, inevitably white, middle-class and mostly male,

247

forming bodies, groups, advisory committees, organisations and councils, writing reviews and reports making recommendations about science and STEM education. Their voices were persistent and influential, rarely grounded in state-sector education themselves, and uninformed by the people upon whom their recommendations and demands might impact. Heavily informed by the needs of business and industry, there was a lack of reference to research, and a lack of criticality in consideration of their recommendations. Rather there seemed to be an unquestioned acceptance that those in a position of privilege should speak to what is best for others. Some of the providers of informal science learning experiences for children and young people, have benefited from the recommendations of such bodies and groups and indeed have been involved in informing such recommendations.

As the STEM agenda continued to be given increasing importance, and indeed it became what might be described as a battleground in relation to the implementation of the Senior Phase of CfE, there was one area in which alignment emerged. The groups, committees and councils and Education Scotland and Scottish Government, supported the notion that science learning beyond the teacher-led, primarily in relation to science centre visits, is beneficial, positive, good for learning and for children. Talk of raising aspiration, inspiring, providing role models and opportunities for 'real-world' experience with 'real scientists' went unchallenged. Again, the deficit model of childhood: children, and by extension their teachers, are not in the 'real-world', and are lacking in aspiration and inspiration. I came to the decision therefore to embark upon research into the role of informal learning in CfE, and to work in one such informal learning setting in Scotland, gaining insight into perceptions of their role, views of teachers, education, learning and children, and the constraints and challenges which are faced when trying to marry the aspiration with reality of bridging formal and informal learning. Throughout, the work contributing to the PhD has been informed by my opportunities to work with pre-service (student) primary and secondary teachers, and qualified primary and secondary teachers, as well as visiting a range of schools through placement visits in my role as a teacher educator with a focus on science education. My research studies have impacted on my role as a teacher educator, broadening and deepening my understanding of education, teaching and learning in science and beyond. This is reflected both in what I teach and how I teach it. For example, a student approached me to ask, "how can I ask children about how I can

improve as a teacher?” My answer was drawn from a rights-based perspective, from my experience with the CRAG and research participants, from my experience as a researcher with a broad overview of the field of children’s voice in science education.

In response to a presentation I gave at a conference in 2015, questions were posed upon which I have reflected a number of times: “Where did this come from? Were you so passionate about children’s voice and children’s rights before, or do you think it is as a result of your PhD?” I have experienced the PhD as a journey of challenging my beliefs, my practice, my thinking and my way of being as a teacher and teacher educator. My belief in education as a means to social justice and the key role of the teacher has strengthened. And, perhaps because I believe that being a teacher is an enactment of who I am as a person committed to children, their wellbeing, their rights and social justice, the journey through the PhD has impacted on me as a person. Did I always hold these beliefs? Yes. Would children I taught recognise me and what drives me as a teacher as being the same as it was? Quite possibly; my intention was always to create a classroom in which children felt safe, confident, listened to and valued, as we worked and learned together. It was not based on a child-deficit model. However, this was enacted more through personal belief and good intention than grounded in a robust, theoretically-based, critical understanding. As a result of my research studies, it is as though viewing the world through a lens which allows me to see further, and deeper than before.

Future research

What do the findings of my research mean for the future? This study is unique in being the first large-scale study in Scotland of children’s perceptions of science experiences beyond the teacher-led and their aspirations for these experiences. Using a children’s rights-based methodology, this thesis offers insight into children’s perceptions of, and aspirations for, science learning beyond the teacher-led, demonstrating that common narratives which currently shape science experiences are not necessarily grounded in evidence. My research also demonstrates that the children’s rights-based methodology can be used on a large scale, and in matters relating to ‘mainstream’ learning and teaching.

By working to improve data from children, it may be possible to improve things for children and by better understanding their experience and perspectives, improve society. It is important not to lose sight of Vygotsky's (1987) assertion that learning leads development. Zaretskii (2009) proposes that as the child interacts with an adult, the ZPD expands: "in other words, not only can children do more independently; what they can do in interaction with an adult also expands" (p. 80). Through enacting CHT using the children's rights-based methodology within this study, development of informed voices gives children the opportunity to develop higher psychological functions, which then gives greater scope for future learning and development. Within my study, I have demonstrated that the opportunity to act as though "a head taller" (Vygotsky, 1978, p. 102) does not require participation by invitation only, the children's rights-based methodology need not be exclusive in order to create a ZPD, contrasting with current practice in children's voice in Scottish schools.

It is evident from this study that children's experiences are different depending on whether or not they like science in school, and their own perceptions of their science ability. In 2010, Falk and Dierking identified that only 5% of an average American's lifespan is spent in school, arguing that "most science is learned out of school" (p. 486). They argued against the "unquestioned focus" in the USA on increasing the number of qualified science teachers to increase the quality of teaching, as a mechanism for increasing scientific literacy. However, this should not be taken by ISIs as a licence to rest on their laurels. Forming ZPDs to enable children's learning and development requires a careful balance of the intellectual and emotional aspects of learning. This does not happen by accident; it requires careful thought and structure. Even if most science is learned out of school it does not follow that science experiences are more beneficial than schools, or that they can contribute to the formal curriculum. ISIs would benefit from a deeper understanding of learning, a vision of what is needed to create ZPDs for children, and how to enact that in reality. The data contained within this study offers, from children's perspectives, the 'ideal' to help children learn and enjoy science more. This is the first step in creating a ZPD; without knowing what the 'ideal' is, it cannot be achieved. In particular, there must be a focus on creating ZPDs for those who do not like learning science in school and who have negative perceptions of their science ability; these children are less likely to report positive experiences and benefits of

science learning beyond the teacher-led than those who like learning science in school and hold positive self-perceptions of ability. There is also opportunity for a focus on those in secondary school, where the liking of learning of science in school does not decline, but enjoyment of visiting places to do with science does.

Can science experiences offer thoughtfully and carefully planned and constructed experiences leading to learning, or are places such as science centres consigned to being an end of term day out (Halcrow Group Limited, 2007, p. 19)? Can they make a difference to children's science learning, achieving something which cannot be achieved in the school setting?

Suggested future research includes employing the children's rights-based methodology used within my study to:

- within schools, explore children's perceptions and experiences of science learning through establishing children's learning advisory groups (CLAGs), and using this to shape learning and teaching in science, and teachers' understanding of children's perspectives in relation to science learning;
- at Scottish Government level, to establish a mechanism for working with children within children's learning science advisory groups (CLSAGs) to inform the development of policy including the next 'STEM strategy' through better data relating to learning science in school and beyond the teacher-led;
- explore through the lens of science capital (DeWitt et al., 2016), external and internal motivators identified as underpinning science experiences beyond the teacher-led;
- cocreate learning opportunities beyond the teacher-led, with particular focus on children who do not like learning science in school and who have negative perceptions of their science abilities.

Despite the support and enthusiasm evident in Scotland, the provision of science learning beyond the teacher-led is simply not meeting the needs of many children nor achieving the aspiration of contributing to the vision of Scotland as a STEM nation. There is a need to bridge the gap between staff in ISIs and qualified teachers, to bridge the informal and formal settings. Coteaching, an approach which has shown very

promising outcomes in relation to teacher education and development of student teachers (see, for example, Bacharach, Heck, & Dahlberg, 2010; Murphy & Martin, 2015; Murphy et al., 2015), presents a way forward; scientists or science communicators with confidence in science, working with qualified teachers with underpinning in pedagogy and learning science, to cocreate and 'deliver' science experiences. A 25-week 'science-in-a-box' programme in Ireland demonstrates such an approach; class teachers and scientists or doctoral science students work together to plan, teach and evaluate science lessons around frontier science (Murphy et al., 2016). Each week the scientist brings to the school a box of materials, supported by ICT-based resources. The project has grown from a single school to a full pilot involving 22 schools, with positive outcomes including evidence of unusually high-levels of scientific understanding and children feeling inspired despite the very challenging nature of the science presented (Murphy et al., 2016). This project, informed by work with a focus on listening to children, includes many of the features which children in my research study call for including participation, interactivity and the kind of enjoyment which comes from being challenged.

My thesis contributes to theory and knowledge by presenting a theoretical and practical operationalisation of Vygotsky's CHT applicable to research which places children at the top of the agenda, through children's participation as coresearchers and research participants. In practice, this translates not just as 'listening' to children but illuminates the use of children's rights-based methodology to create ZPDs for children as coresearchers and as research participants, for adults as coresearchers and for research.

There is an opportunity for ISIs to recognise and address the gap in the experiences of different children. To make a difference, and to play a role in children's learning, requires detailed planning underpinned by children's aspirations and perceptions. Failure to acknowledge the challenges faced by ISIs, arguing only that the lack of evidence of their contribution is due to the complexity of gathering it, or indeed that their contribution would be undermined by attempting to evidence it, is doing children a disservice in Scotland's journey to become a STEM nation (SG, 2017a). There is also an opportunity for children to play an active role in decisions relating to STEM

education, learning and teaching by employing the methodology used within my research to inform and influence policy, and what happens in schools.

This thesis demonstrates that there is an opportunity to use a children's rights-based methodology to gain a much deeper understanding which could shape STEM policy and learning, and progress Scotland's aspirations to be a STEM nation at the forefront of children's rights.

References

- Aberdeen Science Centre. (2018). Meet the Expert Square. Retrieved from <http://aberdeensciencecentre.org/meet-the-expert-james-clerk-maxwell-electromagnetism/meet-the-expert-square-2/>
- Abrahams, I., & Reiss, M. J. (2012). Practical work: Its effectiveness in primary and secondary schools in England. *Journal of Research in Science Teaching*, 49(8), 1035-1055.
- Adams, F. (1997). Does Scotland have a National Curriculum? *Scottish Educational Review*, 29(1), 66-75.
- Agenda. (2018). Paper presented at the Scotland Policy Conferences: Next steps for STEM education and trianing in Scotland: widening participation, improving delivery and meeitng the needs of business, Edinburgh.
<http://www.scotlandpolicyconferences.co.uk/conference/STEM-Scotland-18>
- Ainsworth, H. L., & Eaton, S. E. (2010). *Formal, Non-Formal and Informal Learning in the Sciences* (J. Clydesdale Ed.). Online: Onate Press and Eaton International Consulting Inc.
- Alderman, G. L., & Green, S. K. (2011). Social Powers and Effective Classroom Management. *Intervention in School and Clinic*, 47(1), 39-44. doi:10.1177/1053451211406543
- Alderson, P. (2008). *Young Children's Rights : Exploring Beliefs, Principles and Practice*. London, United Kingdom: Jessica Kingsley Publishers.
- American Physical Society. (2017). *Recruiting Teachers in High-Need STEM Fields: A Survey of Current Majors and Recent STEM Graduates*. Retrieved from Online:
<https://www.aps.org/policy/reports/popa-reports/upload/POPASTEMReport.pdf>
- Amos, R., & Reiss, M. (2012). The Benefits of Residential Fieldwork for School Science: Insights from a five-year initiative for inner-city students in the UK. *International Journal of Science Education*, 34(4), 485-511.
- Archer, L., Osborne, J., Dillon, J., DeWitt, J., Willis, B., & Wong, B. (2013a). *ASPIRES: Young people's science and career aspirations, age 10-14*. Retrieved from Online:
<http://www.kcl.ac.uk/sspp/departments/education/research/ASPIRES/ASPIRES-final-report-December-2013.pdf>
- Archer, L., Osborne, J., Dillon, J., DeWitt, J., Willis, B., & Wong, B. (2013b). *Interim Research Summary, ASPIRES Project What shapes children's science and career aspirations age 10-13?* Retrieved from Online:
<http://www.kcl.ac.uk/sspp/departments/education/research/aspires/aspires-summary-spring-2013.pdf>
- Bacharach, N., Heck, T. W., & Dahlberg, K. (2010). Researching the Use of Coteaching in the Student Teaching Experience. In C. Murphy & K. Scantlebury (Eds.), *Coteaching in*

- International Contexts: Research and Practice* (pp. 35-52). Dordrecht, The Netherlands: Springer Netherlands.
- Bakhtin, M. M. (1984). *Problems of Dostoevsky's Poetics* (C. Emerson, Trans. C. Emerson Ed. Vol. 8). Minneapolis, United States of America: University of Minnesota Press.
- Bakhtin, M. M. (1986). *Speech genres and other late essays*. Austin, Texas, United States of America: University of Texas Press.
- Bamberger, Y., & Tal, T. (2007). Learning in a personal context: Levels of choice in a free choice learning environment in science and natural history museums. *Science Education*, 91(1), 75-95. doi:10.1002/sce.20174
- Bamberger, Y., & Tal, T. (2008). An Experience for the Lifelong Journey: The Long-Term Effect of a Class Visit to a Science Center. *Visitor Studies*, 11(2), 198-212. doi:10.1080/10645570802355760
- Bao, L., Cai, T., Koenig, K., Fang, K., Han, J., Wang, J., . . . Wu, N. (2009). Physics: Learning and scientific reasoning. *Science*, 323(5914), 586. doi:10.1126/science.1167740
- Baram-Tsabari, A., & Osborne, J. (2015). Bridging science education and science communication research. *Journal of Research in Science Teaching*, 52(2), 135-144. doi:10.1002/tea.21202
- Barker, B. S., Larson, K., & Krehbiel, M. (2014). Bridging Formal and Informal Learning Environments. *Journal of Extension*, 52(5), [5IAW5].
- Beazley, H., Bessell, S., Ennew, J., & Waterson, R. (2009). The right to be properly researched: research with children in a messy, real world. *Children's Geographies*, 7(4), 365-378. doi:10.1080/14733280903234428
- Bell, A. (2007). Designing and testing questionnaires for children. *Journal of Research in Nursing*, 12(5), 461-469. doi:10.1177/1744987107079616
- Bell, P., Lewenstein, B., Shouse, A. W., & Feder, M. A. (2009). *National Research Council Committee on Learning Science in Informal Environments: People, Places, and Pursuits* Retrieved from <http://elib.tcd.ie/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=eric&AN=ED536350&site=eds-live>
http://www.nap.edu/catalog.php?record_id=12190
- Bennett, J., & Hogarth, S. (2009). Would you want to talk to a scientist at a party? High school students attitudes to school science and to science. *International Journal of Science Education*, 31(14), 1975-1998. doi:10.1080/09500690802425581
- Bevan, B., & Dillon, J. (2010). Broadening Views of Learning: Developing Educators for the 21st Century Through an International Research Partnership at the Exploratorium and King's College London. *New Educator.*, 6(3/4), 167-180.

- Biesta, G. (2008). What kind of citizen? What kind of democracy? Citizenship education and the Scottish Curriculum for Excellence. *Scottish Educational Review*, 40(2), 38-52.
- Biesta, G. (2009). Good education in an age of measurement: on the need to reconnect with the question of purpose in education. *Educational Assessment, Evaluation & Accountability*, 21(1), 33.
- Billson, J. M. (1986). The College Classroom as a Small Group: Some Implications for Teaching and Learning. *Teaching Sociology* <http://www.jstor.org/stable/1318467>. *Teaching Sociology*, 14(3), 143-151.
- Bloomer, K. (2016). Reforming Scotland: What Future for Scottish Education. *Reforming Scotland Melting Pot*, 30. Retrieved from Reform Scotland website: <https://reformscotland.com/wp-content/uploads/2016/06/What-future-for-Scottish-education.pdf>
- Bodrova, E., Germeroth, C., & Leong, D. J. (2013). Play and Self-Regulation: Lessons from Vygotsky. *American Journal of Play*, 6(111-123).
- Bowers, R. (2005). Freire (with Bakhtin) and the Dialogic Classroom Seminar. *Alberta Journal of Educational Research*, 51(4), 368-378.
- Bowker, R. (2010). *Understanding the role of informal learning in children's educational development [electronic resource]*. (Ph.D.), University of Exeter, United Kingdom, Exeter, United Kingdom.
- Bracken, S. (2010). Discussing the importance of ontology and epistemology awareness in practitioner research. *Worcester Journal of Learning and Teaching*(4).
- Bragg, S. (2001). Taking a Joke: learning from the voices we don't want to hear. *Forum*, 43(2), 70-73.
- Bragg, S. (2007). 'But I listen to children anyway!'—teacher perspectives on pupil voice. *Educational Action Research*, 15(4), 505-518. doi:10.1080/09650790701663973
- British Broadcasting Corporation. (2003). Big Idea facing closure. Retrieved from BBC News website: <http://news.bbc.co.uk/1/hi/scotland/3171669.stm>
- British Educational Research Association. (2011). *Ethical Guidelines for Educational Research*. London, United Kingdom: British Educational Research Association.
- Bruck, M., Ceci, S. J., & Melnyk, L. (1997). External and internal sources of variation in the creation of false reports in children. *Learning & Individual Differences*, 9(4), 289.
- Brummelman, E., Thomaes, S., Nelemans, S. A., Orobio de Castro, B., Overbeek, G., & Bushman, B. J. (2015). Origins of narcissism in children. *Proceedings of the National Academy of Sciences of the United States of America*, 112(12), 3659-3662. doi:10.1073/pnas.1420870112

- Brunell, A. B., Gentry, W. A., Campbell, W. K., Hoffman, B. J., Kuhnert, K. W., & DeMarree, K. G. (2008). Leader Emergence: The Case of the Narcissistic Leader. *Personality and Social Psychology Bulletin*, 34(12), 1663-1676. doi:10.1177/0146167208324101
- Brunell, A. B., Tumblin, L., & Buelow, M. T. (2014). Narcissism and the Motivation to Engage in Volunteerism. *Current Psychology*, 33(3), 365-376. doi:10.1007/s12144-014-9216-7
- Bryce, S. (2015). *STEM Education Support Officer Report*. Online: Scottish Government
Retrieved from
<http://www.gov.scot/Topics/Education/Schools/curriculum/STEM/STEMEC/Papers/STEMEdSupportOffReport>.
- Bryman, A. (2007). Barriers to Integrating Quantitative and Qualitative Research. *Journal of Mixed Methods Research*, 1(1), 8-22.
- Buntting, C., Gunstone, R., Corrigan, D., Dillon, J., & Jones, A. (2015). The Future in Learning Science: Themes, Issues and Big Ideas. In D. Corrigan, C. Buntting, J. Dillon, A. Jones, & R. Gunstone (Eds.), *The Future in Learning Science: What's in it for the Learner?* (1st ed., pp. 1-17). London, United Kingdom: Springer International Publishing.
- Bussey, K. (1995). Allegations of Child Sexual Abuse - Accurate and Truthful Disclosures, False Allegations and False Denials. *Current Issues in Criminal Justice*, 7(2), 176-192.
- Bybee, R. W. (2001). Achieving Scientific Literacy. In J. H. Falk, E. Donovan, & R. Woods (Eds.), *Free-Choice Science Education: How we Learn Science Outside of School* (pp. 44-63). Columbia University, New York, United States of America: Teachers College Press.
- Campbell, I. (2007). Chi-squared and Fisher-Irwin tests of two-by-two tables with small sample recommendations. *Statistics in medicine*, 26(19), 3661-3675. doi:10.1002/sim.2832
- Chaiklin, S. (2003). The Zone of Proximal Development in Vygotsky's Analysis of Learning and Instruction. In A. Kozulin, B. Gindis, V. S. Ageyev, & S. M. Miller (Eds.), *Vygotsky's educational theory in cultural context*. (pp. 39-64). Cambridge, United Kingdom: Cambridge University Press.
- Chaiklin, S. (2011). Social Scientific Research and Societal Practice: Action Research and Cultural-Historical Research in Methodological Light from Kurt Lewin and Lev S. Vygotsky. *Mind, Culture, and Activity*, 18(2), 129-147.
doi:10.1080/10749039.2010.513752
- Chaiklin, S. (2012). A conceptual perspective for investigating motive in cultural-historical theory. In M. Hedegaard, A. Edwards, & M. Fleer (Eds.), *Motives in children's development: Cultural-historical approaches*. (pp. 209-224). New York, United States of America: Cambridge University Press.
- Champagne, D. W. (1975). The Ontario Science Centre: Some Impressions and Some Questions. *Educational Technology*, 15(8), 36-39.

- Children's Research Advisory Group (CRAG). (2016a). CRAG experience.
<https://drive.google.com/open?id=0B816yG9ZahKYTFdKSzhXNmZ1YkU>.
- Children's Research Advisory Group (CRAG). (2016b). CRAG is Fab.
<https://drive.google.com/open?id=0B816yG9ZahKYcGVPbEpqck5idmc>.
- Clark, A. (2004). The Mosaic Approach and Research with Young Children. In V. Lewis, M. Kellett, C. Robinson, S. Fraser, & S. Ding (Eds.), *The Reality of Research with Children and Young People* (pp. 142-156). London, United Kingdom: Sage Publications in association with the Open University.
- Cocks, A. J. (2006). The Ethical Maze: Finding an Inclusive Path towards Gaining Children's Agreement to Research Participation. *Childhood*, 13(2), 247-266.
- Cohen, L., Manion, L., & Morrison, K. (2011). *Research Methods in Education* (7th ed.). Abingdon Oxon, United Kingdom: Routledge, Taylor & Francis Group.
- Convery, A. (2017). 'There is no alternative': Scotland's curriculum for excellence and its relationship with high culture. *Scottish Affairs*, 26(2), 176-193.
doi:10.3366/scot.2017.0177
- Cook-Sather, A. (2007). Resisting the Impositional Potential of Student Voice Work: Lessons for liberatory educational research from poststructuralist feminist critiques of critical pedagogy. *Discourse: Studies in the Cultural Politics of Education*, 28(3), 389-403.
doi:10.1080/01596300701458962
- Cook-Sather, A. (2014). The trajectory of student voice in educational research. *New Zealand Journal of Educational Studies*, 49(2), 131-148.
- Cornelius, S., & Shanks, R. (2016). Expectations and challenges: the implementation of mobile devices in a Scottish primary school. *Technology, Pedagogy and Education*, 1-13.
doi:10.1080/1475939X.2016.1153513
- Costello, A. B., & Osborne, J. (2005). Best practices in exploratory factor analysis: four recommendations for getting the most from your analysis. *Practical Assessment, Research and Evaluation*, 10(7), 1-9.
- Cox-Petersen, A. M., Marsh, D. D., Kisiel, J., & Melber, L. M. (2003). Investigation of Guided School Tours, Student Learning, and Science Reform Recommendations at a Museum of Natural History. *Journal of Research in Science Teaching*, 40(2), 200-218.
doi:10.1002/tea.10072
- Csikszentmihalyi, M. (2002). *Flow : the classic work on how to achieve happiness* (Revised and updated ed.). London, United Kingdom: Rider.
- Davenport, S. W., Bergman, S. M., Bergman, J. Z., & Fearing, M. E. (2014). Twitter versus Facebook: Exploring the role of narcissism in the motives and usage of different social media platforms. *Computers in Human Behavior*, 32, 212-220.
doi:<https://doi.org/10.1016/j.chb.2013.12.011>

- Davies, A. (2014). Does Anonymising Steal the Voices of Researchers and Research Subjects? In W. Midgley, A. Davies, M. E. Oliver, & P. A. Danaher (Eds.), *Echoes: Ethics and Issues of Voice in Education Research* (pp. 25-33). Rotterdam, The Netherlands: Sense Publishers.
- Davydov, V. V., & Kerr, S. T. (1995). The Influence of L. S. Vygotsky on Education Theory, Research, and Practice. *Educational Researcher*, 24(3), 12-21. doi:10.2307/1176020
- Dawson, E. (2014). "Not Designed for Us": How Science Museums and Science Centers Socially Exclude Low-Income, Minority Ethnic Groups. *Science Education*, 98(6), 981-1008. doi:10.1002/sce.21133
- Denholm, A. (2017, 3 September 2017). Top academic criticises 'disastrous' curriculum. *The Herald*. Retrieved from http://www.heraldscotland.com/news/15511922.Top_academic_criticises____disastrous____curriculum/
- Derry, J. (2013). *Vygotsky: Philosophy and Education*. Chichester, United Kingdom: Wiley-Blackwell.
- DeWitt, J., Archer, L., & Mau, A. (2016). Dimensions of science capital: exploring its potential for understanding students' science participation. *International Journal of Science Education*, 38(16), 2431-2449. doi:10.1080/09500693.2016.1248520
- DeWitt, J., Archer, L., & Osborne, J. (2014). Science-related Aspirations Across the Primary–Secondary Divide: Evidence from two surveys in England. *International Journal of Science Education*, 36(10), 1609-1629. doi:10.1080/09500693.2013.871659
- DeWitt, J., & Osborne, J. (2010). Recollections of Exhibits: Stimulated-recall interviews with primary school children about science centre visits. *International Journal of Science Education*, 32(10), 1365-1388. doi:10.1080/09500690903085664
- Dierking, L. D. (1991). Learning Theory and Learning Styles: An Overview. *The Journal of Museum Education*, 16(1), 4-6. doi:10.2307/40478871
- Dillon, J. (2013). Doing justice to the informal science education community. *Studies in Science Education*, 50(1), 131-136. doi:10.1080/03057267.2013.831971
- Disclosure Scotland. (n.d.). Protecting Vulnerable Groups Scheme (PVG Scheme). Retrieved from <https://www.disclosurescotland.co.uk/disclosureinformation/pvgscheme.htm>
- Donaldson, G. (2014). Teacher Education and Curriculum Change in Scotland. *European Journal of Education*, 49(2), 178-191. doi:10.1111/ejed.12077
- Dong, J., & Dong, Y. (2013). Voicing as an Essential Problem of Communication: Language and Education of Chinese Immigrant Children in Globalization. *Anthropology & Education Quarterly*, 44(2), 161-176. doi:10.1111/aeq.12013
- Draper, S. W. (1999). Analysing fun as a candidate software requirement. *Personal and Ubiquitous Computing*, 3(3), 117-122. doi:10.1007/BF01305336

- Drew, V., & Mackie, L. (2011). Extending the constructs of active learning: implications for teachers' pedagogy and practice. *The Curriculum Journal*, 22(4), 451-467.
doi:10.1080/09585176.2011.627204
- Dundee Science Centre. (2011). *Science and Engineering Education Advisory Group Catalogue of Evidence: Dundee Science Centre outreach: creating a culture of engagement with science*. Online: Scottish Government Retrieved from
<http://www.gov.scot/Topics/Education/Schools/curriculum/ACE/Science/SEEAG/CatalogueofEvidence/DundeeScienceCentreOutreach>.
- Dundee Science Centre. (2018a). About us. Retrieved from
<http://www.dundeesciencecentre.org.uk/about-us/about-us/>
- Dundee Science Centre. (2018b). Meet the Expert. Retrieved from
<http://www.dundeesciencecentre.org.uk/local/events/event.php?eventgroupID=168&categoryID=9>
- Dynamic Earth. (2018a). About Us. Retrieved from <http://www.dynamicearth.co.uk/about-us>
- Dynamic Earth. (2018b). Operation Earth. Retrieved from
<http://www.dynamicearth.co.uk/learning/operation-earth>
- Edinburgh International Science Festival. (2015). Education. Retrieved from
<http://www.sciencefestival.co.uk/education>
- Education Scotland. (2012). *The Sciences 3-18 Curriculum Impact Report*. Retrieved from Online:
http://www.educationscotland.gov.uk/Images/Sciences3to182013Update_tcm4-817013.pdf
- Education Scotland. (2013a). *Health and wellbeing: the responsibility of all 3-18 Curriculum Impact Report*. Retrieved from Online:
http://www.educationscotland.gov.uk/Images/HealthandWellbeing3to18_tcm4-814360.pdf
- Education Scotland. (2013b). *The Sciences 3-18 Curriculum Impact Report Update*. Retrieved from Online:
http://www.educationscotland.gov.uk/Images/Sciences3to182013Update_tcm4-817013.pdf
- Education Scotland. (2015). *Inspection Advice Note 2015-16*. Retrieved from Online:
http://www.educationscotland.gov.uk/resources/i/genericresource_tcm4865189.asp
- Education Scotland. (n.d.-a). Inspection and Review. Retrieved from
<http://www.educationscotland.gov.uk/inspectionandreview/>
- Education Scotland. (n.d.-b). Learning and Teaching. Retrieved from
<http://www.educationscotland.gov.uk/learningandteaching/>

- Egan, K., & Gajdamaschko, N. (2003). Some Cognitive Tools of Literacy. In A. Kozulin, B. Gindis, V. S. Ageyev, & S. M. Miller (Eds.), *Vygotsky's educational theory in cultural context* (pp. 83-98). Cambridge, United Kingdom: Cambridge University Press.
- El'Konin, B. D. (2001). L.S. Vygotsky and D.B. El'konin. *Journal of Russian & East European Psychology*, 39(4), 9.
- Emerson, L. (n.d.). Profile. Retrieved from [http://pure.qub.ac.uk/portal/en/persons/lesley-emerson\(9ca39bdd-a303-449a-9ca1-7e445e761d9a\).html](http://pure.qub.ac.uk/portal/en/persons/lesley-emerson(9ca39bdd-a303-449a-9ca1-7e445e761d9a).html)
- Emerson, L., Lloyd, K., Lundy, L., Orr, K., & Weaver, E. (2014). *The Legal Needs of Children and Young People in Northern Ireland: the views of young people and adult stakeholders*. Retrieved from Belfast, Northern Ireland:
- Emerson, L., Orr, K., & Connolly, P. (2014). *Evaluation of the effectiveness of the 'prison to peace: learning from the experience of political ex-prisoners' educational programme*. Retrieved from Belfast: Northern Ireland: Queen's University Belfast
- Eraut, M. (2000). Non-formal learning, implicit learning and tacit knowledge in professional work. In F. E. Coffield (Ed.), *The Necessity of Informal Learning* (pp. 12-31). Bristol, United Kingdom: Policy Press.
- Eshach, H. (2007). Bridging In-School and Out-of-School Learning: Formal, Non-Formal, and Informal Education. *Journal of Science Education and Technology*, 16(2), 171-190.
- Falk, J. H. (2001). Free-Choice Science Learning: Framing the Discussion. In J. H. Falk (Ed.), *Free-choice Science Education: How We Learn Science Outside of School* (pp. 3-20). Columbia University, New York, United States of America: Teachers College Press.
- Falk, J. H. (2005). Free-Choice Environmental Learning: Framing the Discussion. *Environmental Education Research*, 11(3), 265-280.
- Falk, J. H., & Dierking, L. D. (1997). School field trips: assessing their long-term impact. *Curator*, 40, 211-218. doi:10.1111/j.2151-6952.1997.tb01304.x
- Falk, J. H., & Dierking, L. D. (2002). *Lessons Without Limit: How Free-choice Learning is Transforming Education*. Oxford, United Kingdom: AltaMira Press.
- Falk, J. H., & Dierking, L. D. (2010). The 95 Percent Solution. *American Scientist*, 98(6), 486-493. doi:<http://dx.doi.org/10.1511/2010.87.486>
- Falk, J. H., Dierking, L. D., Osborne, J., Wenger, M., Dawson, E., & Wong, B. (2015). Analyzing Science Education in the United Kingdom: Taking a System-Wide Approach. *Science Education*, 99(1), 145-173. doi:10.1002/sce.21140
- Falk, J. H., Osborne, J., Dierking, L. D., Dawson, E., Wenger, M., & Wong, B. (2012). *Analysing the UK Science Education Community: The contribution of informal providers*. Retrieved from Online:
http://www.wellcome.ac.uk/stellent/groups/corporatesite/@msh_peda/documents/web_document/wtp040860.pdf

- Falk, J. H., & Storksdieck, M. (2005). Using the Contextual Model of Learning to Understand Visitor Learning from a Science Center Exhibition. *Science Education*, 89(5), 744-778.
- Fani, T., & Ghaemi, F. (2011). Implications of Vygotsky's Zone of Proximal Development (ZPD) in Teacher Education: ZPTD and Self-scaffolding. *Procedia - Social and Behavioral Sciences*, 29, 1549-1554. doi:<https://doi.org/10.1016/j.sbspro.2011.11.396>
- Farmer, S., Finlayson, M., Kibble, B., & Roach, A. (2006). *The ROSE Survey in Scotland - An Initial Report Views of Secondary 3 Pupils on the Relevance of Science Education*. Retrieved from Online: http://www.gla.ac.uk/media/media_51342_en.pdf
- Feiman-Nemser, S. (2001). From Preparation to Practice: Designing a Continuum to Strengthen and Sustain Teaching. *Teachers College Record*, 103(6), 1013-1055.
- Fensham, P. J. (2015). Connoisseurs of Science: A Next Goal for Science Education? In D. Corrigan, C. Buntting, J. Dillon, A. Jones, & R. Gunstone (Eds.), *The Future in Learning Science: What's in it for the Learner?* (1st ed. ed., pp. 35-39). London, United Kingdom: Springer International Publishing.
- Field, A. (2000, 3 December 2010). Research Methods I: SPSS for Windows Part 5 Relationship between Variables. Retrieved from <http://www.discoveringstatistics.com/docs/correlation.pdf>
- Field, A. (2005a). *C8057 (Research Methods II): Factor Analysis on SPSS extracted from Field (2005)*. Lecture notes. University of Sussex. Online. Retrieved from http://www.bwgriffin.com/gsu/courses/edur9131/content/Neill2008_WritingUpAFactorAnalysis.pdf
- Field, A. (2005b). *Discovering statistics using SPSS* (2nd ed.). London, United Kingdom: Sage Publications.
- Fielding, M. (2001a). Beyond the Rhetoric of Student Voice: new departures or new constraints in the transformation of 21st century schooling? *Forum*, 43(2), 100-112.
- Fielding, M. (2001b). Editorial. *Forum*, 43(2), 49-50. Retrieved from <http://dx.doi.org/10.2304/forum.2001.43.2.1>
- Fielding, M. (2001c). Students as Radical Agents of Change. *Journal of Educational Change*, 2(2), 123-141. doi:10.1023/A:1017949213447
- Fielding, M. (2004). Transformative approaches to student voice: theoretical underpinnings, recalcitrant realities. *British Educational Research Journal*, 30(2), 295-311. doi:10.1080/0141192042000195236
- Finlayson, M., & Roach, A. (2007). *The ROSE Survey in Scotland - An Extension Survey of Younger Pupils*. Retrieved from Online: http://www.gla.ac.uk/media/media_51343_en.pdf
- Fischbacher, C. M. (2014). *Identifying "deprived individuals": are there better alternatives to the Scottish Index of Multiple Deprivation (SIMD) for socioeconomic targeting in*

- individually based programmes addressing health inequalities in Scotland?* Retrieved from Online: <http://www.scotpho.org.uk/media/1166/scotpho140109-simd-identifyingdeprivedindividuals.pdf>
- Flynn, P. (2013). The Transformative Potential in Student Voice Research for Young People Identified with Social, Emotional and Behavioural Difficulties. *Trinity Education Papers Special Issue: Examining Theory & Practice in Inclusive Education*, 2(2).
- Flynn, P. (2014). Empowerment and transformation for young people with social, emotional and behavioural difficulties engaged with student voice research. *New Zealand Journal of Educational Studies*, 49(2), 162-175.
- Flynn, P., Shevlin, M., & Lodge, A. (2011). Are You Listening? I'm Me! *Reach*, 25(1), 60-74.
- Flynn, P., Shevlin, M., & Lodge, A. (2012). Pupil voice and participation. Empowering children with emotional and behavioural difficulties. In T. Cole, H. Daniels, & J. Visser (Eds.), *The Routledge international companion to emotional and behavioural difficulties* (pp. 246-263). Oxon, United Kingdom: Routledge.
- Franklin, B. (2002). Introduction. In B. Franklin (Ed.), *The new handbook of children's rights : comparative policy and practice* (2nd ed., pp. 1-12). London, United Kingdom: Routledge.
- Franz-Odendaal, T. A., Blotnicky, K., French, F., & Joy, P. (2016). Experiences and Perceptions of STEM Subjects, Careers, and Engagement in STEM Activities Among Middle School Students in the Maritime Provinces. *Canadian Journal of Science, Mathematics and Technology Education*, 16(2), 153-168. doi:10.1080/14926156.2016.1166291
- Freeman, T. (2015). Scottish Government must stop 'self-congratulation' says educationalist. *Holyrood*. Retrieved from Holyrood website: <https://www.holyrood.com/articles/news/scottish-government-must-stop-%E2%80%98self-congratulation%E2%80%99-says-educationalist>
- Freire, P. (2005). *Pedagogy of the Oppressed: 30th Anniversary Edition* (30th anniversary ed.). New York, United States of America: Continuum.
- Frontier Economics. (2009). *Assessing the impact of science centres in England: a report prepared for Business, Innovation and Skills*. Retrieved from London, United Kingdom: http://sciencecentres.org.uk/govreport/docs/impact_of_science_centres.pdf
- Frymier, A. B., & Houser, M. L. (2000). The teacher-student relationship as an interpersonal relationship. *Communication Education*, 49(3), 207-219.
- Gallimore, R., & Tharp, R. G. (1990). Teaching mind in society: Teaching, schooling, and literature discourse. In L. C. Moll (Ed.), *Vygotsky and education: instructional implications and applications of sociohistorical psychology* (pp. 175-205). Cambridge, United Kingdom: Cambridge University Press.

- Gardner, H. (1991). *The unschooled mind: how children think and how schools should teach*. New York, United States of America: BasicBooks.
- General Teaching Council for Scotland. (2012a). *The Standards for Leadership and Management*. Retrieved from Online: <http://www.gtcs.org.uk/web/FILES/the-standards/standards-for-leadership-and-management-1212.pdf>
- General Teaching Council for Scotland. (2012b). *The Standards for Registration*. Retrieved from Online: <http://www.gtcs.org.uk/web/files/the-standards/standards-for-registration-1212.pdf>
- Giroux, H. (2003). Public Time and Educated Hope: Educational Leadership and the War Against Youth. *The Initiative Anthology*. Retrieved from The Initiative Anthology: An electronic publication about Leadership, Culture and Schooling website: <http://www.units.miamioh.edu/eduleadership/anthology/OA/OA03001.html>
- Glasgow Science Centre. (2015). Bodyworks on Tour for Schools. Retrieved from <http://www.glasgowsciencecentre.org/on-tour/bodyworks-on-tour-for-schools.html>
- Glasgow Science Centre. (2018a). Freedom of Information. Retrieved from <https://www.glasgowsciencecentre.org/freedom-information>
- Glasgow Science Centre. (2018b). Meet the Expert. Retrieved from <https://www.glasgowsciencecentre.org/discover/shows-and-workshops/meet-expert>
- Glasgow Science Centre Charitable Trust. (2014). *Annual Report and Financial Statements*. Retrieved from Online: <https://www.aspenpeople.co.uk/GSC/docs/GSCCT%20acts%202014.pdf>
- Glasgow Science Centre Charitable Trust. (2015). *Annual Report and Financial Statements*. Retrieved from Online: <https://www.aspenpeople.co.uk/GSC/docs/GSCCT%20acts%202015.pdf>
- Government of Ireland. (2012). *Guidance for Developing Ethical Research Projects involving Children*. Online: Government of Ireland Retrieved from http://www.dcy.gov.ie/documents/Publications/Ethics_Guidance.pdf.
- Graham, A., & Fitzgerald, R. (2010). Progressing children's participation: Exploring the potential of a dialogical turn. *Childhood*, 17(3), 343-359. doi:10.1177/0907568210369219
- Gray, P. (2010). Fun in theory and practice: new teachers, pupil opinion and classroom environments. In J. McNally & A. Blake (Eds.), *Improving Learning in a Professional Context: A Research Perspective on the New Teacher in School* (pp. 121-136). Oxon, United Kingdom: Routledge Taylor & Francis Group.
- Great Britain: Department for Education. (2013, 16 July 2014). The national curriculum for England to be taught in all local authority-maintained schools. *National curriculum*. Retrieved from <https://www.gov.uk/government/collections/national-curriculum>

- Great Britain: Department for Education. (2014, 10 January 2014). FOI Release: Number of schools, teachers and students in England. Retrieved from <https://www.gov.uk/government/publications/number-of-schools-teachers-and-students-in-england/number-of-schools-teachers-and-students-in-england>
- Great Britain: Department for Education and Skills. (2006). *The Science, Technology, Engineering and Mathematics (STEM) Report*. Online: Great Britain: Department for Education and Skills Retrieved from https://www.nationalstemcentre.org.uk/.../stem_programme_report_2006.
- Great Britain: House of Commons Select Committee on Science and Technology. (2007). *Eleventh Report*. London, United Kingdom: HM Stationery Office Retrieved from <https://publications.parliament.uk/pa/cm200607/cmselect/cmsctech/903/90302.htm>.
- Great Britain: Parliament: House of Commons Science and Technology Committee. (2007). *The Funding of Science and Discovery Centres: Eleventh Report of Session 2006-07, Vol. 2: Oral and Written Evidence*. (9780215036629). London, United Kingdom: The Stationery Office Ltd Retrieved from <https://publications.parliament.uk/pa/cm200607/cmselect/cmsctech/903/903ii.pdf>.
- Great Britain: Parliamentary Office of Science and Technology. (2011). POSTNOTE Informal STEM Education. In G. B. P. O. o. S. a. Technology (Ed.), (Vol. 382). Online: Great Britain: Parliamentary Office of Science and Technology.
- Gredler, M. E. (2012). Understanding Vygotsky for the Classroom: Is It Too Late? *Educational Psychology Review*, 24(1), 113-131.
- Gredler, M. E. (2018). Lev Vygotsky (1896–1934) - Cultural-Historical Theory, Education and Cognitive Development. Retrieved from <http://education.stateuniversity.com/pages/2539/Vygotsky-Lev-1896-1934.html>
- Greene, J. C. (2008). Is mixed methods social inquiry a distinctive methodology? *Journal of Mixed Methods Research*, 2(1), 7-22.
- Griffin, J. (2004). Research on students and museums: Looking more closely at the students in school groups. *Science Education*, 88(S1), S59-S70. doi:10.1002/sce.20018
- Griffin, J., & Symington, D. (1997). Moving from task-oriented to learning-oriented strategies on school excursions to museums. *Science Education*, 81, 763-779. doi:10.1002/(SICI)1098-237X(199711)81:6<763::AID-SCE11>3.0.CO;2-O
- Gwet, K. L. (2014). Intrarater Reliability. In N. Balakrishnan (Ed.), *Methods and Applications of Statistics in Clinical Trials: Planning, Analysis, and Inferential Methods* (Vol. 2, pp. 340-356). Hoboken, NJ, United States of America: John Wiley & Sons.
- Haladyna, T., Olsen, R., & Shaughnessy, J. (1982). Relations of Student, Teacher, and Learning Environment Variables to Attitudes Toward Science. *Science Education*, 66(5).

- Haladyna, T., Olsen, R., & Shaughnessy, J. (1983). Correlates of Class Attitudes Toward Science. *Journal of Research in Science Teaching*, 20(4).
- Halcrow Group Limited. (2007). *Scotland's Science Centres - Impacts and Future Interventions*. Online: Scottish Government Retrieved from <http://www.gov.scot/Publications/2007/11/02154710/14>.
- Harlen, W. (Ed.) (2010). *Principles and Big Ideas of Science Education*. Hatfield, United Kingdom: Association for Science Education.
- Hayward, L. (2015). Assessment is learning: the preposition vanishes. *Assessment in Education: Principles, Policy & Practice*, 22(1), 27-43. doi:10.1080/0969594X.2014.984656
- Hazen, R. M. (2002). Why Should You Be Scientifically Literate? *Bioscience*, December 2002.
- Heal, S. (2008). Science centres: hard facts needed. *Museums Journal*, 108(1). Retrieved from Museum Association website: <https://www.museumsassociation.org/museums-journal/news/15466>
- Hedge, N., & MacKenzie, A. (2016). Scotland's Curriculum for Excellence: a defence of autonomy and personhood. *OXFORD REVIEW OF EDUCATION*, 42(1), 1-15. doi:10.1080/03054985.2015.1128890
- Hendrickx, M. M. H. G., Mainhard, M. T., Boor-Klip, H. J., Cillessen, A. H. M., & Brekelmans, M. (2016). Social dynamics in the classroom: Teacher support and conflict and the peer ecology. *Teaching and Teacher Education*, 53(Supplement C), 30-40. doi:<https://doi.org/10.1016/j.tate.2015.10.004>
- Hepburn, H. (2018). Scottish study flags up lack of opportunities for black and minority ethnic teachers. *Times Educational Supplement*, 4 May 2018(2571). Retrieved from Times Educational Supplement website: <https://www.tes.com/news/scottish-study-flags-lack-opportunities-black-and-minority-ethnic-teachers>
- HM Inspectorate of Education. (2007). *Review of the Contribution of the Scottish Science Centres Network to Formal and Informal Science Education*. Online: Education Scotland Retrieved from www.educationscotland.gov.uk/inspectionandreview/.../sscn_tcm4-7128...
- HM Inspectorate of Education. (2009). *Review of the Contribution of the Scottish Science Centre Network to Formal and Informal Science Education: Report of Follow-Through Visits by HM Inspectorate of Education - June 2009*. Online: Education Scotland Retrieved from www.educationscotland.gov.uk/.../ScienceCentresFT_tcm4-712913.pdf.
- Hobbiss, M. (2017). 'Liking' vs 'wanting': A neuroscientific view on classroom motivation. Retrieved from <https://npjsciencecommunity.nature.com/users/33200-mike-hobbiss/posts/16652-liking-vs-wanting-a-neuroscientific-view-on-classroom-motivation>

- Holbrook, J., & Rannikmae, M. (2009). The meaning of scientific literacy. *International Journal of Environmental and Science Education*, 4(3), 275-288.
- Hood, J. N., Jacobson, R. P., & Jacobson, K. J. L. (2017). The Impact of Self-Esteem and Empathy on the Relationship between Workplace Bullying and Attachment Style. *Review of Integrative Business & Economics Research*, 6(4), 104 - 118.
- Howe, A. C. (1996). Development of science concepts within a Vygotskian framework. *Science Education*, 80(1), 35-51. doi:10.1002/(SICI)1098-237X(199601)80:1<35::AID-SCE3>3.0.CO;2-3
- Humes, W. (2013). The Origins and Development of Curriculum for Excellence: Discourse, Politics and Control. In M. Priestley & G. Biesta (Eds.), *Reinventing the Curriculum: New Trends in Curriculum Policy and Practice* (pp. 13-34). London, United Kingdom: Bloomsbury.
- Hutcheson, G., & Sofroniou, N. (1999). *The multivariate social scientist introductory statistics using generalized linear models*. London, United Kingdom: Sage Publications.
- ICT in Education Excellence Group. (2013). *Final Report*. Retrieved from Online: <https://www.webarchive.org.uk/wayback/archive/20170110104245/http://www.gov.scot/Resource/0041/00412968.pdf>
- Illingworth, S., Lewis, E., & Percival, C. (2015). Does attending a large science event enthuse young people about science careers? *Journal of Science Communication*, 14(02), 16. Retrieved from http://jcom.sissa.it/sites/default/files/documents/JCOM_1402_2015_A06.pdf
- IMAX Corporation. (2013). Cineworld Group and IMAX(R) expand revenue share partnership [Press release]. Retrieved from <https://www.imax.com/content/cineworld-group-and-imax%C2%AE-expand-revenue-share-partnership>
- Institute for Medical Science and Technology. (2016). About IMSAT. Retrieved from <http://www.imsat.org/AboutIMSaT.htm>
- 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:<http://dx.doi.org/10.1016/j.learninstruc.2015.03.003>
- Jenkins, E. W. (2005). The Student Voice in Science Education: Research and Issues. *Journal of Baltic Science Education*(7), 22-30.
- Jenkins, E. W. (2006). The Student Voice and School Science Education. *Studies in Science Education*, 42(1), 49-88. doi:10.1080/03057260608560220

- Jerome, L., Emerson, L., Lundy, L., & Orr, K. (2015). *Teaching and learning about child rights: a study of implementation in 26 countries*. Retrieved from Online:
<http://eprints.mdx.ac.uk/18078/1/Filetoupload%2C515480%2Cen.pdf>
- John, M. (1996). In Whose Best Interest? In M. John (Ed.), *Children in Our Charge: the Child's Right to Resources* (Vol. 2, pp. 3-16). London, United Kingdom: Jessica Kingsley.
- John, M. (2001). Achieving Respect for Children's Views in Education: Roles for Adults and Children. In S. N. Hart, C. P. Cohen, M. F. Erickson, & M. Flekkoy (Eds.), *Children's Rights in Education* (pp. 136-154). London, United Kingdom: Jessica Kingsley.
- Jones, M. G. (1998, 18 - 22 February 1998). *Creating Electronic Learning Environments: Games, Flow and the User Interfact*. Paper presented at the National Convention of the Association for Educational Communications and Theory (AECT).
- Juffermans, K., & Van der Aa, J. (2013). Introduction to the Special Issue: Analyzing Voice in Educational Discourses. *Anthropology & Education Quarterly*, 44(2), 112-123.
doi:10.1111/aeq.12010
- Kellett, M. (2009). Children and young people's participation. In H. Montgomery & M. Kellett (Eds.), *Children and young people's worlds: developing frameworks for integrated practice* (pp. 43-60). Bristol, United Kingdom: Policy Press & The Open University.
- Kellett, M., Forrest, R., Dent, N., & Ward, S. (2004). 'Just teach us the skills please, we'll do the rest': empowering ten-year-olds as active researchers. *Children & Society*, 18(5), 329-343. doi:10.1002/chi.807
- Kim, S. (2013). Neuroscientific model of motivational process (Vol. 4: 98). *Frontiers in Psychology*.
- Kincheloe, J. L. (2011). *Key Works in Critical Pedagogy* (K. Hayes, S. R. Steinberg, & K. G. Tobin Eds. Vol. 32). Rotterdam, The Netherlands: Sense Publishers.
- King, H., & DeWitt, J. (n.d.). A framing narrative for collaborative partnerships supporting research and learning in Informal Science Institutions. Retrieved from King's College London Centre for Public Policy Research website:
<http://www.kcl.ac.uk/sspp/departments/education/research/cppr/workingpapers/Paper-6.pdf>
- King, H., & Glackin, M. (2010). Supporting Science Learning in Out-of-School Contexts. In J. Osborne & J. Dillon (Eds.), *Good Practice in Science Teaching What Research has to Say* (Second ed., pp. 259-273). Maidenhead, Berkshire, United Kingdom: Open University Press, McGraw Hill.
- King, H., Steiner, K., Hobson, M., Robinson, A., & Clipson, H. (2015). Highlighting the value of evidence-based evaluation: pushing back on demands for 'impact'. *Journal of Science Communication*, 14(2), 1-11. Retrieved from
http://jcom.sissa.it/archive/14/02/JCOM_1402_2015_A02

- Kirby, P. (2001). Participatory Research in Schools. *Forum*, 43(2), 74-77.
- Kisiel, J. F. (2003). Teachers, Museums and Worksheets: A Closer Look at a Learning Experience. *Journal of Science Teacher Education*, 14(1), 3-21.
- Kisiel, J. F. (2014). Clarifying the complexities of school–museum interactions: Perspectives from two communities. *Journal of Research in Science Teaching*, 51(3), 342-367. doi:10.1002/tea.21129
- Konrath, S., Ho, M.-H., & Zarins, S. (2016). The Strategic Helper: Narcissism and Prosocial Motives and Behaviors. *Current Psychology*, 35(2), 182-194. doi:10.1007/s12144-016-9417-3
- Koshmanova, T. (2009). *Methodological Legacy of Vygotsky*. Saarbruecken, Germany: VDM Publishing.
- Kowalski, C. J. (1972). On the Effects of Non-Normality on the Distribution of the Sample Product-Moment Correlation Coefficient. *Journal of the Royal Statistical Society. Series C (Applied Statistics)*, 21(1), 1-12. doi:10.2307/2346598
- Kravtsova, E. E. (2006). The Concept of Age-Specific New Psychological Formations in Contemporary Developmental Psychology. *Journal of Russian & East European Psychology*, 44(6), 6-18. doi:10.2753/RPO1061-0405440601
- Kravtsova, E. E. (2007). Vygotsky's Approach to Education. *Children in Europe, Rediscovering Vygotsky Special Publication*, 8-9.
- Kravtsova, E. E. (2009). The cultural-historical foundations of the zone of proximal development. *Journal of Russian & East European Psychology*, 47(6), 9-24. doi:10.2753/RPO1061-0405470601
- Kuchah, K., & Pinter, A. (2012). 'Was this an interview?' Breaking the power barrier in adult-child interviews in an African context. *Issues in Educational Research*, 22(3), 283-297.
- Lantolf, J. P. (2003). Intrapersonal Communication and Internalization in the Second Language. In A. Kozulin, B. Gindis, V. S. Ageyev, & S. M. Miller (Eds.), *Vygotsky's educational theory in cultural context* (pp. 349-370). Cambridge, United Kingdom: Cambridge University Press.
- Learning and Teaching Scotland. (2009). *Curriculum for Excellence: Sciences Principles and Practice*. Online: Education Scotland Retrieved from http://www.educationscotland.gov.uk/Images/sciences_principles_practice_tcm4-540396.pdf.
- Leney, T., & Ponton, A. (2007). *Country Background Report United Kingdom*. Retrieved from Online: <http://www.oecd.org/edu/skills-beyond-school/recognitionofnon-formalandinformallearning-participatingcountrieswithrelateddocumentsandpublications.htm>

- Lenz, G. S., & Lawson, C. (2011). Looking the part: Television leads less informed citizens to vote based on candidates' appearance. *American Journal of Political Science*, 55(3), 574-589. doi:10.1111/j.1540-5907.2011.00511.x
- Leonardi, S., Lamb, H., Howe, P., & Choudhury, A. (2017). 'State of the nation' report of UK primary science education: Baseline research for the Wellcome Trust Primary Science Campaign. Retrieved from Online:
- Levykh, M. G. (2008). The Affective Establishment and Maintenance of Vygotsky's Zone of Proximal Development. *Educational Theory*, 58(1), 83-101. doi:10.1111/j.1741-5446.2007.00277.x
- Lewenstein, B. V. (2015). Identifying what matters: Science education, science communication, and democracy. *Journal of Research in Science Teaching*, 52(2), 253-262. doi:10.1002/tea.21201
- Lewis, A. (1992). Group child interviews as a research tool. *British Educational Research Journal*, 18(4), 413.
- Lewis, A. (2010). Silence in the Context of 'Child Voice'. *Children & Society*, 24(1), 14-23. doi:10.1111/j.1099-0860.2008.00200.x
- Lincoln, Y. (1993). I and thou: method, voice, and roles in research with the silenced. In D. McLaughlin & W. G. Tierney (Eds.), *Naming silenced lives: personal narratives and the process of educational change* (pp. 29-47). London, United Kingdom: Routledge.
- Lloyd, R., Neilson, R., King, S., & Dyball, M. (2012). *Science Beyond the Classroom: Review of Informal Science Learning*. Retrieved from Online:
http://www.wellcome.ac.uk/stellent/groups/corporatesite/@msh_peda/documents/web_document/wtp040862.pdf
- Lortie, D. C. (1975). *School teacher a sociological study*. Chicago, United States of America: University of Chicago Press.
- Lucas, K. B. (2000). One teacher's agenda for a class visit to an interactive science center. *Science Education*, 84(4), 524-544.
- Lundy, L. (2007). 'Voice' is not enough: conceptualising Article 12 of the United Nations Convention on the Rights of the Child. *British Educational Research Journal*, 33(6), 927-942. doi:10.1080/01411920701657033
- Lundy, L. (2012). Children's rights and educational policy in Europe: the implementation of the United Nations Convention on the Rights of the Child. *OXFORD REVIEW OF EDUCATION*, 38(4), 393-411. doi:10.1080/03054985.2012.704874
- Lundy, L. (2016). *Children's Rights and Participation: How to win 'friends' and influence people?* Paper presented at the Contemporary Childhood Conference, Young Citizens and Society: Fostering Civic Participation, University of Strathclyde, Glasgow, United Kingdom.

- Lundy, L., & Cook-Sather, A. (2015). Children's Rights and Student Voice: Their Intersections and the Implications for Curriculum and Pedagogy. In D. Wyse, L. Hayward, & J. Pandya (Eds.), *The SAGE Handbook of Curriculum, Pedagogy and Assessment* (1st edition. ed., Vol. 1, pp. 263-277). Thousand Oaks, California, United States of America: Sage Publications.
- Lundy, L., & McEvoy, L. (2008). *E-consultation with Pupils: A Pilot Study*. Retrieved from Bangor, Northern Ireland: Northern Ireland Statistics and Research Agency, Department for Education Northern Ireland
- Lundy, L., & McEvoy, L. (2009). Developing outcomes for educational services: a children's rights-based approach. *Effective Education*, 1(1), 43-60.
doi:10.1080/19415530903044050
- Lundy, L., & McEvoy, L. (2011). Children's rights and research processes: Assisting children to (in)formed views. *Childhood*, 19(1), 1-16. doi:10.1177/0907568211409078
- Lundy, L., & McEvoy, L. (2012). Childhood, the United Nations Convention on the Rights of the Child and Research: What Constitutes a 'Rights-Based' Approach? In M. Freeman (Ed.), *Law and Childhood Studies: Current Legal Issues* (Vol. 14, pp. 75-91). Oxford, United Kingdom: Oxford University Press.
- Lundy, L., McEvoy, L., & Byrne, B. (2011). Working with Young Children as Co-Researchers: An Approach Informed by the United Nations Convention on the Rights of the Child. *Early Education and Development*, 22(5), 714-736. doi:10.1080/10409289.2011.596463
- Macedo, D. P., & Freire, P. (1995). A Dialogue: Culture, Language, and Race. *Harvard Educational Review*, 65(3), 377-402.
- Mack, E., Augare, H., Different Cloud-Jones, L., David, D., Quiver Gaddie, H., Honey, R., . . . Wippert, R. (2012). Effective practices for creating transformative informal science education programs grounded in Native ways of knowing. *Cultural Studies of Science Education*, 7, 49-70. doi:10.1007/s11422-011-9374-y
- MacNab, S. (2015, 20 May 2015). Scotland's education record is 'national scandal'. *The Scotsman*. Retrieved from <https://www.scotsman.com/news/education/scotland-s-education-record-is-national-scandal-1-3778583>
- MacNab, S. (2016, 7 December 2016). Education figures are another blot on the SNP's report card. *The Scotsman*. Retrieved from <https://www.scotsman.com/news/opinion/scott-macnab-education-figures-are-another-blot-on-the-snp-s-report-card-1-4310640>
- Mahn, H. (2003). Periods in Child Development. In A. Kozulin, B. Gindis, V. S. Ageyev, & S. M. Miller (Eds.), *Vygotsky's Educational Theory in Cultural Context* (pp. 119-138). Cambridge, United Kingdom: Cambridge University Press.
- Marshall, C., Byrne, B., & Lundy, L. (2015). Face to Face: Children and Young People's Right to Participate in Public Decision-Making. In T. Gal & B. F. Duramy (Eds.), *International*

- Perspectives and Empirical Findings on Child Participation* (pp. 357-380). Oxford, United Kingdom: Oxford University Press.
- Mason, S. P., & Cohen, C. P. (2001). Children's Rights in Education. In S. N. Hart, C. P. Cohen, M. F. Erickson, & M. Flekkoy (Eds.), *Children's Rights in Education* (pp. 15-36). London, United Kingdom: Jessica Kingsley.
- Matterson, C., & Holman, J. (2012). *Informal Science Learning Review: Reflections from the Wellcome Trust*. Retrieved from Online:
<https://wellcomelibrary.org/item/b21248047#?c=0&m=0&s=0&cv=0>
- Matthews, S. H. (2007). A Window on the 'New' Sociology of Childhood. *Sociology Compass*, 1(1), 322-334. doi:10.1111/j.1751-9020.2007.00001.x
- Maxwell, B., & DesRoches, S. (2010). Empathy and social-emotional learning: Pitfalls and touchstones for school-based programs. *New Directions for Child and Adolescent Development*, 2010(129), 33-53. doi:10.1002/cd.274
- McCambridge, J., Witton, J., & Elbourne, D. R. (2014). Systematic review of the Hawthorne effect: New concepts are needed to study research participation effects. *Journal of Clinical Epidemiology*, 67(3), 267-277. doi:10.1016/j.jclinepi.2013.08.015
- McCluskey, G., Brown, J., Munn, P., Lloyd, G., Hamilton, L., Sharp, S., & Macleod, G. (2013). 'Take more time to actually listen': students' reflections on participation and negotiation in school. *British Educational Research Journal*, 39(2), 287-301. doi:10.1080/01411926.2012.659720
- McCully, A., & Emerson, L. (2014). Teaching controversial issues in conflict and in transition to peace: an analysis of policy and practice in Northern Ireland. In T. Misco & J. De Groof (Eds.), *Cross-Cultural Case Studies of Teaching Controversial Issues: Pathways and Challenges to Democratic Citizenship Education*: Wolf Legal Publishers.
- McLeish, T. (2017). STEM teaching put on the endangered list. Retrieved from
<http://blogs.royalsociety.org/in-verba/2017/06/07/stem-teaching-put-on-the-endangered-list/>
- McManus, I. C., & Furnham, A. (2010). "Fun, Fun, Fun": Types of Fun, Attitudes to Fun, and their Relation to Personality and Biographical Factors. *Psychology*, 01(03), 10. doi:10.4236/psych.2010.13021
- Mellor, D., & Moore, K. A. (2014). The Use of Likert Scales With Children. *Journal of Pediatric Psychology*, 39(3), 369-379. doi:10.1093/jpepsy/jst079
- Mercer, N., Dawes, L., Wegerif, R., & Sams, C. (2004). Reasoning as a scientist: ways of helping children to use language to learn science. *British Educational Research Journal*, 30(3), 359-377. doi:10.1080/01411920410001689689

- Mesquita, G. R. (2012). Vygotsky and the Theories of Emotions: in search of a possible dialogue. *Psicologia: Reflexão e Crítica*, 25(4), 809-816. doi:10.1590/S0102-79722012000400021
- Mewborn, D. S., & Tyminski, A. M. (2006). Lortie's Apprenticeship of Observation Revisited. *For the Learning of Mathematics*, 26(3), 30-33.
- Midgley, W., Davies, A., Oliver, M. E., & Danaher, P. A. (2014). The Echoes of Voice in Education Research Ethics. In W. Midgley, A. Davies, M. E. Oliver, & P. A. Danaher (Eds.), *Echoes: Ethics and Issues of Voice in Education Research* (pp. 2-10). Rotterdam, The Netherlands: Sense Publishers.
- Mithra, H. G. (2014). Paulo Freire's Educational Theory and Approach: A Critique. *Asia Journal of Theology*, 28(1), 96-118.
- Moll, L. C. (Ed.) (1990). *Vygotsky and education: instructional implications and applications of sociohistorical psychology*. Cambridge, United Kingdom: Cambridge University Press.
- Morris Hargreaves McIntyre. (2011). *Final Visitor Research Report 2008-10: Scottish Science Centre Evaluation*. Online: Scottish Government Retrieved from <http://www.gov.scot/Publications/2011/01/11104751/0>.
- Morrow, V., & Richards, M. (1996). The Ethics of Social Research with Children: An Overview. *Children & Society*, 10(2), 90-105.
- Mowat, J. G. (2018). Closing the attainment gap – a realistic proposition or an elusive pipe-dream? *Journal of Education Policy*, 33(2), 299-321. doi:10.1080/02680939.2017.1352033
- Muijs, D. (2010). *Doing Quantitative Research in Education with SPSS* (2nd ed.). London, United Kingdom: Sage Publications.
- Mujtaba, T., Lawrence, M., Oliver, M., & Reiss, M. J. (2018). Learning and engagement through natural history museums. *Studies in Science Education*, 54(1), 41-67.
- Murphy, C. (2012). Vygotsky and Primary Science. In B. J. Fraser, K. Tobin, & C. J. McRobbie (Eds.), *Second International Handbook of Science Education* (Vol. 24, pp. 177-187). The Netherlands: Springer.
- Murphy, C. (2015). Reconceptualising the Learning and Teaching of Scientific Concepts. In D. Corrigan, C. Buntting, J. Dillon, A. Jones, & R. Gunstone (Eds.), *The Future in Learning Science: What's in it for the Learner?* (1st ed. ed., pp. 127-150). London, United Kingdom: Springer International Publishing.
- Murphy, C., & Beggs, J. (2003). Children's perception of school science. *School Science Review*, 84(308), 109 - 116.
- Murphy, C., Beggs, J., Carlisle, K., & Greenwood, J. (2004). Students as 'catalysts' in the classroom: the impact of co-teaching between science student teachers and primary

- classroom teachers on children's enjoyment and learning of science. *International Journal of Science Education*, 26(8), 1023-1035. doi:10.1080/1468181032000158381
- Murphy, C., Kerr, K., Lundy, L., & McEvoy, L. (2010). *Attitudes of Children and Parents to Key Stage 2 Science Testing and Assessment: Final Report to the Wellcome Trust*. Retrieved from Online:
http://www.wellcome.ac.uk/stellent/groups/corporatesite/@msh_peda/documents/web_document/wtx062721.pdf
- Murphy, C., Lundy, L., Emerson, L., & Kerr, K. (2013). Children's perceptions of primary science assessment in England and Wales. *British Educational Research Journal*, 39(3), 585-606. doi:10.1080/01411926.2012.674921
- Murphy, C., & Martin, S. N. (2015). Editorial: Coteaching in teacher education: research and practice. *Asia-Pacific Journal of Teacher Education*, 43(4), 277-280.
doi:10.1080/1359866X.2015.1060927
- Murphy, C., Mullaghy, M., & D'Arcy, A. (2016). 'Scientists are not always right, but they do their best.' Irish children's perspectives of innovations in science teaching and learning. *School Science Review*, 98(362), 55-65.
- Murphy, C., Scantlebury, K., & Milne, C. (2015). Using Vygotsky's zone of proximal development to propose and test an explanatory model for conceptualising coteaching in pre-service science teacher education. *Asia-Pacific Journal of Teacher Education*, 43(4), 281-295. doi:10.1080/1359866X.2015.1060291
- Murtagh, C. (2010). Curriculum for Excellence faces fresh hurdles. *Holyrood*. Retrieved from Holyrood website: <http://legacy.holyrood.com/2010/03/preparing-for-takeoff/>
- National Records of Scotland. (2011). Scotland's Census 2011 Table DSC1117SC - Age by Sex. Online: National Records of Scotland.
- Neill, J. (2008). *Writing up a Factor Analysis: summarised extract from Neill (1994)*. Centre of Applied Psychology. University of Canberra. Online. Retrieved from
http://www.bwgriffin.com/gsu/courses/edur9131/content/Neill2008_WritingUpAFactorAnalysis.pdf
- Noyes, A. (2005). Pupil choice: purpose, power and the possibilities for democratic schooling. *British Educational Research Journal*, 31(4), 533-540.
- Nundy, S. (1999). The Fieldwork Effect: The Role and Impact of Fieldwork in the Upper Primary School. *International Research in Geographical and Environmental Education*, 8(2), 190-198. doi:10.1080/10382049908667608
- Nunes, T., Bryant, P., Strand, S., Hillier, J., Barros, R., & Miller-Friedman, J. (2017). *Review of SES and Science Learning in Formal Educational Settings*. Retrieved from Online:
- O'Neill, J. (2014). Voice and the ethics of children's agency in education research. *New Zealand Journal of Educational Studies*, 49(2), 219-231.

- O'Reilly, C. A., Doerr, B., Caldwell, D. F., & Chatman, J. A. (2014). Narcissistic CEOs and executive compensation. *The Leadership Quarterly*, 25(2), 218-231.
doi:<https://doi.org/10.1016/j.leaqua.2013.08.002>
- Organisation for Economic Cooperation and Development. (2015a). *The ABC of Gender Equality in Education: Aptitude, Behaviour, Confidence*. Retrieved from Online:
http://www.oecd-ilibrary.org/education/the-abc-of-gender-equality-in-education_9789264229945-en
- Organisation for Economic Cooperation and Development. (2015b). Improving School in Scotland: An OECD Perspective. Retrieved from <http://www.oecd.org/edu/skills-beyond-school/recognitionofnon-formalandinformallearning-home.htm>
- Organisation for Economic Cooperation and Development. (2016a). *PISA 2015 Results (Volume II): Policies and Practices for Successful Schools*. Retrieved from Paris, France:
https://read.oecd-ilibrary.org/education/pisa-2015-results-volume-ii_9789264267510-en#page4
- Organisation for Economic Cooperation and Development. (2016b). Recognition of Non-formal and Informal Learning - Home. Retrieved from <http://www.oecd.org/edu/skills-beyond-school/recognitionofnon-formalandinformallearning-home.htm>
- Organisation for Economic Cooperation and Development. (2018). Programme for International Student Assessment (PISA). Retrieved from <http://www.oecd.org/pisa/>
- Orr, K., Emerson, L., Lundy, L., Royal-Dawson, L., & Jimenez, E. (2016). *Enabling the Exercise of Civil and Political Rights: The Views of Children*. Retrieved from Online:
<http://resourcecentre.savethechildren.se/library/enabling-exercise-civil-and-political-rights-views-children>
- Osborne, J., & Dillon, J. (2007). Research on learning in informal contexts: advancing the field? (Vol. 29, pp. 1441-1445). United Kingdom.
- Osborne, J., Simon, S., & Collins, S. (2003). Attitudes towards science: A review of the literature and its implications. *International Journal of Science Education*, 25(9), 1049-1079.
doi:10.1080/0950069032000032199
- Pallant, J. (2010). *SPSS survival manual: a step by step guide to data analysis using SPSS* (4th ed.). Maidenhead, United Kingdom: McGraw-Hill.
- Patel, S., DeMaine, S., Heafield, J., Bianchi, L., & Prokop, A. (2017). The drososchools project: Long-term scientist-teacher collaborations to promote science communication and education in schools. *Seminars in Cell & Developmental Biology*, 70, 73-84.
doi:<https://doi.org/10.1016/j.semcdb.2017.07.025>
- Pell, T., & Jarvis, T. (2001). Developing attitude to science scales for use with children of ages from five to eleven years. *International Journal of Science Education*, 23(8), 847-862.
doi:10.1080/09500690010016111

- Pennings, H. J. M., van Tartwijk, J., Wubbels, T., Claessens, L. C. A., van der Want, A. C., & Brekelmans, M. (2014). Real-time teacher–student interactions: A Dynamic Systems approach. *Teaching and Teacher Education*, 37, 183-193.
doi:10.1016/j.tate.2013.07.016
- Perry, D. L. (2012). *What makes learning fun? : principles for the design of intrinsically motivating museum exhibits*. Lanham, Maryland, United States of America: AltaMira Press.
- Phillips, L. (2014). Research with Children: Voice, Agency and Transparency. In W. Midgley, A. Davies, M. E. Oliver, & P. A. Danaher (Eds.), *Echoes: Ethics and Issues of Voice in Education Research* (pp. 165-184). Rotterdam, The Netherlands: Sense Publishers.
- Phillips, M., Finkelstein, D., & Wever-Frerichs, S. (2007). School Site to Museum Floor: How informal science institutions work with schools. *International Journal of Science Education*, 29(12), 1489-1507. doi:10.1080/09500690701494084
- Priestley, M. (2010). Curriculum for Excellence: transformational change or business as usual? *Scottish Educational Review*, 42(1), 23-36.
- Priestley, M., & Biesta, G. (2013). Introduction: The New Curriculum. In M. Priestley & G. Biesta (Eds.), *Reinventing the Curriculum: New Trends in Curriculum Policy and Practice* (pp. 1-12). London, United Kingdom: Bloomsbury.
- Priestley, M., & Humes, W. (2010). The development of Scotland's Curriculum for Excellence: amnesia and déjà vu. *OXFORD REVIEW OF EDUCATION*, 36(3), 345-361.
doi:10.1080/03054980903518951
- Priestley, M., & Miller, K. (2012). Educational change in Scotland: policy, context and biography. *Curriculum Journal*, 23(1), 99-116. doi:10.1080/09585176.2012.650490
- Priestley, M., & Minty, S. (2012). *Developing Curriculum for Excellence Summary of findings from research undertaken in a Scottish local authority*. Retrieved from Online:
http://www.stir.ac.uk/media/schools/education/documents/projectdocuments/StirlingCfEresearch-report_March2012.pdf
- Priestley, M., & Minty, S. (2013). Curriculum for Excellence: "A brilliant idea, but..." (Vol. 45, pp. 39-52). United Kingdom.
- Priestley, M., Minty, S., & Eager, M. (2014). School-Based Curriculum Development in Scotland: Curriculum Policy and Enactment. *Pedagogy, Culture and Society*, 22(2), 189-211.
- Punch, S. (2004). Negotiating Information: Children's Use of Time and Space in Rural Bolivia. In V. Lewis, M. Kellett, C. Robinson, S. Fraser, & S. Ding (Eds.), *The Reality of Research with Children and Young People* (pp. 94-114). London, United Kingdom: Sage Publications in association with the Open University.
- Qvortrup, L. (2008). The first global education forum. *Teacher Education Quarterly*, 1(2).

- Rahm, J. (2014). Reframing Research on Informal Teaching and Learning in Science: Comments and Commentary at the Heart of a New Vision for the Field. *Journal of Research in Science Teaching*, 51(3), 395-406. doi:10.1002/tea.21141
- Rahmani, L. (1973). *Soviet Psychology: Philosophical, Theoretical, and Experimental Issues*. New York, United States of America: International Univs. Press.
- Reiss, M. J. (2015). Learning for a Better World: Futures in Science Education. In D. Corrigan, C. Bunting, J. Dillon, A. Jones, & R. Gunstone (Eds.), *The Future in Learning Science: What's in it for the Learner?* (1st ed. ed., pp. 19-35). London, United Kingdom: Springer International Publishing.
- Rennie, L. J. (2014). Learning Science Outside of School. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of Research on Science Education* (Vol. 2, pp. 120-144). New York, United States of America: Routledge.
- Rennie, L. J., Feher, E., Dierking, L. D., & Falk, J. H. (2003). Toward an Agenda for Advancing Research on Science Learning in Out-of-School Settings. *Journal of Research in Science Teaching*, 40(2), 112-120. doi:10.1002/tea.10067
- Rennie, L. J., & McClafferty, T. P. (1996). Science Centres and Science Learning. *Studies in Science Education*, 27, 53-98.
- Resnick, L. B. (1987). The 1987 Presidential Address: Learning in School and out. *Educational Researcher*, 16(9), 13-54. doi:10.2307/1175725
- Reynolds-Keefer, L., & Johnson, R. (2011). Is a Picture Is Worth a Thousand Words? Creating Effective Questionnaires with Pictures. *Practical Assessment*, 16(8), 1-7.
- Richardson, J. T. E. (2011). The analysis of 2×2 contingency tables-Yet again. *Statistics in medicine*, 30(8), 890-890. doi:10.1002/sim.4116
- Robbins, D. (2010). What is Vygotskian Cultural-Historical Theory? Retrieved from University of Central Missouri website:
<http://faculty.ucmo.edu/drobbins/pdf/vygotskianculthist.pdf>
- Robinson, C., & Taylor, C. (2007). Theorizing Student Voice: Values and Perspectives. *Improving Schools*, 10(1), 5-17.
- Roche, J. (1996). Children's Rights: A Lawyer's View. In M. John (Ed.), *Children in Our Charge: the Child's Right to Resources* (Vol. 2, pp. 23-35). London, United Kingdom: Jessica Kingsley.
- Rodd, M., Reiss, M., & Mujtaba, T. (2013). Undergraduates talk about their choice to study physics at university: what was key to their participation? *Research in Science & Technological Education*, 31(2), 153-167. doi:10.1080/02635143.2013.811072

- Roth, W.-M., & Radford, L. (2010). Re/thinking the Zone of Proximal Development (Symmetrically). *Mind, Culture, and Activity*, 17(4), 299-307.
doi:10.1080/10749031003775038
- Royal Observatory Edinburgh. (n.d.). New focus on science education for Royal Observatory Edinburgh Visitor Centre [Press release]. Retrieved from
<http://www.roe.ac.uk/roe/support/pr/pressreleases/vcfuture.html>
- Rubtsov, V. (2007). Making shared learning work. *Children in Europe, Rediscovering Vygotsky Special Publication*, 12-13.
- Rudduck, J. (2006). The past, the papers and the project. *Educational Review*, 58(2), 131-143.
doi:10.1080/00131910600583993
- Rudduck, J., & Fielding, M. (2006). Student voice and the perils of popularity. *Educational Review*, 58(2), 219-231. doi:10.1080/00131910600584207
- Sacco, K., Falk, J. H., & Bell, J. (2014). Informal Science Education: Lifelong, Life-Wide, Life-Deep. *PLoS Biology*, 12(11), 1-3. doi:10.1371/journal.pbio.1001986
- Salmi, H. (2003). Science centres as learning laboratories: experiences of Heureka, the Finnish Science Centre. *International Journal of Technology Management*, 25(5), 460-476.
- Schauble, L., Gleason, M., Lehrer, R., Bartlett, K., Petrosino, A., Allen, A., . . . Street, J. (2002). Supporting science learning in museums. In G. Leinhardt, K. Crowley, K. Knutson, G. Leinhardt, K. Crowley, & K. Knutson (Eds.), *Learning conversations in museums* (pp. 425-452). Mahwah, New Jersey, United States of America: Lawrence Erlbaum Associates Publishers.
- Schreiner, C., & Sjoberg, S. (2004). *Sowing the seeds of ROSE. Background, Rationale, Questionnaire Development and Data Collection for ROSE (The Relevance of Science Education) - a comparative study of students' view of science and science education*. Retrieved from Oslo:
<http://www.uv.uio.no/ils/english/research/projects/rose/actadidactica.pdf>
- Schugurensky, D. (2000, n.d.). The Forms of Informal Learning: Towards a Conceptualisation of the Field. *New Approaches to Lifelong Learning (NALL)*. Retrieved from
<https://tspace.library.utoronto.ca/bitstream/1807/2733/2/19formsofinformal.pdf>
- Schunk, D. H. (1991). Self-Efficacy and Academic Motivation. *Educational Psychologist*, 26(3-4), 207-231. doi:10.1080/00461520.1991.9653133
- Science and Engineering Education Advisory Group. (2012). *Supporting Scotland's STEM Education and Culture*. Retrieved from Edinburgh, Scotland:
<http://www.gov.scot/Publications/2012/02/4589>
- Scottish Executive. (2000). *Teaching Profession for the 21st Century: Report of the Committee of Inquiry into Professional Conditions of Service for Teachers (the McCrone Report)*. Edinburgh, Scotland: HM Stationery Office.

- Scottish Executive. (2002). *The National Debate on Education: Briefing Pack*. Online: Scottish Executive Retrieved from <http://www.gov.scot/Publications/2002/03/10806/File-1>.
- Scottish Executive. (2004a). *A Curriculum for Excellence - Ministerial Response*. (0-7559-4373-2). Edinburgh, Scotland: Scottish Executive Retrieved from <http://www.gov.scot/Publications/2004/11/20175/45849>.
- Scottish Executive. (2004b). *A Curriculum for Excellence: The Curriculum Review Group*. (ISBN: 0-7559-4215-9). Edinburgh, Scotland: Scottish Executive Retrieved from <http://www.scotland.gov.uk/Resource/Doc/26800/0023690.pdf>.
- Scottish Executive. (2005a). *Assessment of Achievement: Sixth Survey of Science 2003*. Online: Scottish Executive Retrieved from <http://www.gov.scot/Resource/Doc/37428/0009599.pdf>.
- Scottish Executive. (2005b). *The Scottish Science Centres Network: 2005-2009*. Online: Scottish Executive Retrieved from www.gov.scot/Resource/Doc/47121/0020462.pdf.
- Scottish Government. (2008). *Curriculum for Excellence Building the Curriculum 3 A Framework for Learning and Teaching*. Edinburgh, Scotland: Scottish Government.
- Scottish Government. (2009). *Curriculum for Excellence Building the Curriculum 4 Skills for Learning, Skills for Life and Skills for Work*. Edinburgh, Scotland: Scottish Government.
- Scottish Government. (2011). *Consultation on Rights of Children and Young People Bill*. Online: Scottish Government Retrieved from <http://www.gov.scot/Resource/Doc/357438/0120726.pdf>.
- Scottish Government. (2012, 11 December 2012). Summary Statistics for Schools in Scotland, No.3: 2012 Edition. No.3: 2012 Edition. Retrieved from <http://www.gov.scot/Publications/2012/12/2355/0>
- Scottish Government. (2013a). Science festivals get 2014 boost [Press release]. Retrieved from <http://news.scotland.gov.uk/News/Science-festivals-get-2014-boost-790.aspx>
- Scottish Government. (2013b, 13 May 2013). Scottish Index of Multiple Deprivation Frequently Asked Questions. Retrieved from <http://www.gov.scot/Topics/Statistics/SIMD/FAQUsingSIMD#a8#a8>
- Scottish Government. (2013c, 10 January 2013). SIMD Postcode Lookup. Retrieved from <http://www.gov.scot/Topics/Statistics/SIMD/SIMDPostcodeLookup>
- Scottish Government. (2014a). £2.5 million boost for science [Press release]. Retrieved from <http://news.scotland.gov.uk/News/-2-5-million-boost-for-science-b4b.aspx>
- Scottish Government. (2014b, November 2014). Scottish Government Urban Rural Classification 2013-2014: Overview. Retrieved from <http://www.gov.scot/Publications/2014/11/2763/2#table2.1>
- Scottish Government. (2015a). £2.75m boost for science [Press release]. Retrieved from <http://news.scotland.gov.uk/News/-2-75m-boost-for-science-1620.aspx>

Scottish Government. (2015b). Celebration of Science [Press release]. Retrieved from <http://news.scotland.gov.uk/News/Celebration-of-science-19f1.aspx>

Scottish Government. (2015c, 16 August 2016). The Scottish Attainment Challenge,. Retrieved from <http://www.gov.scot/Topics/Education/Schools/Raisingeducationalattainment>

Scottish Government. (2015d, n.d.). Scottish Science Festivals. Retrieved from <http://www.gov.scot/Topics/Business-Industry/science/Scienceengagement/sciencefestivals>

Scottish Government. (2016, 3 November 2017). The Scottish Index of Multiple Deprivation. Retrieved from <http://www.gov.scot/Topics/Statistics/SIMD/>

Scottish Government. (2017a). Making Scotland a STEM nation [Press release]. Retrieved from <https://news.gov.scot/news/making-scotland-a-stem-nation>

Scottish Government. (2017b). Science and Research. Retrieved from <https://beta.gov.scot/policies/science-and-research/science-engagement/>

Scottish Government. (2017c). *Science, Technology, Engineering and Mathematics (STEM) Evidence Base*. Online: Scottish Government Retrieved from <http://www.gov.scot/Resource/0052/00526537.pdf>.

Scottish Government. (2017d, 2017). The Scottish National Standardised Assessment. Retrieved from <https://standardisedassessment.gov.scot/>

Scottish Government. (2017e, 22 September 2017). STEM Strategy for Education and Training Reference Group. Retrieved from <https://www.webarchive.org.uk/wayback/archive/20180129210127/http://www.gov.scot/Topics/Education/Schools/curriculum/STEM/ReferenceGroup>

Scottish Government. (2018a, 5 March 2018). Getting it right for every child (GIRFEC).

Scottish Government. (2018b). *STEM and languages choice in school: Young People in Scotland Survey 2017*. Online: Scottish Government Retrieved from <https://beta.gov.scot/publications/young-people-in-scotland-survey-2017-stem-and-language-findings/>.

Scottish Government. (2018c). Year of Young people. Retrieved from <http://yoyp2018.scot/what-is-yoyp/>

Scottish Government. (2018d). *Young People's Participation in Decision Making in Scotland: Attitudes and Perceptions*. Online: Scottish Government Retrieved from <http://www.gov.scot/Resource/0053/00531021.pdf>.

Scottish Government. (n.d.-a). Pupil attainment: closing the gap. Retrieved from <https://beta.gov.scot/policies/schools/pupil-attainment/>

Scottish Government. (n.d.-b, n.d.). Science and Engineering Education Advisory Group Catalogue of Evidence. Retrieved from

- <http://www.gov.scot/Topics/Education/Schools/curriculum/ACE/Science/SEEAG/CatalogueofEvidence>
- Scottish Office Education Department. (1993). *The Structure and Balance of the Curriculum 5-14: Curriculum and Assessment in Scotland National Guidelines*. (5/93). Edinburgh, Scotland: Scottish Office Education Department,.
- Scottish Parliament Education and Skills Committee. (2017). *Teacher Workforce Planning for Scotland's Schools*. Retrieved from Online:
<https://digitalpublications.parliament.scot/Committees/Report/ES/2017/9/1/Teacher-Workforce-Planning-for-Scotland-s-Schools#Recruitment-and-initial-teacher-education--ITE->
- Scottish Science Advisory Committee. (2003). *Why Science Education Matters: Supporting and Improving Science Education in Scottish Schools*. Retrieved from Online:
http://www.scots.org.uk/news/Science_Report.pdf
- Scottish Science Advisory Council. (2011). *Science Education: Enhancing Support for Schools Through Collaboration*. Retrieved from Online:
http://www.scottishscience.org.uk/sites/default/files/article-attachments/SSAC%20Science%20Education%20Report_0.pdf
- Scottish Science Advisory Council. (n.d., n.d.). RSE announces Scottish Science Advisory Committee Membership. Retrieved from
<http://www.scottishscience.org.uk/article/rse-announces-scottish-science-advisory-committee-membership>
- Sher, J., Gwanzura-Ottemoller, F., Tisdall, K., & Milne, S. (2010a). *Having a Say at School Research Briefing Paper 2: Characteristics of Pupil Councils*. Retrieved from Online:
<http://www.havingasayatschool.org.uk/documents/HASASResearchBriefing5--April2010.pdf>
- Sher, J., Gwanzura-Ottemoller, F., Tisdall, K., & Milne, S. (2010b). *Having a Say at School Research Briefing Paper 4: Pupil Council 'Effectiveness' - Part One: Processes*. Retrieved from Online: http://www.havingasayatschool.org.uk/documents/paper4_001.pdf
- Sher, J., Gwanzura-Ottemoller, F., Tisdall, K., & Milne, S. (2010c). *Having a Say at School Research Briefing Paper 5: Pupil Council 'Effectiveness' - Part Two: Outcomes*. Retrieved from Online:
<http://www.havingasayatschool.org.uk/documents/HASASResearchBriefing5--April2010.pdf>
- Silva, E. (2001). Squeaky Wheels and Flat Tyres: a case study of students as reform participants. *Forum*, 43(2), 95-99.

- Sjoberg, S., & Schreiner, C. (2010). *The ROSE project An overview and key findings*. Retrieved from Online: <http://roseproject.no/network/countries/norway/eng/nor-Sjoberg-Schreiner-overview-2010.pdf>
- Smith, M. K. (1997, 2002). Paulo Freire: dialogue, praxis and education. *The Encyclopedia of Informal Education*. Retrieved from infed.org website: <http://infed.org/mobi/paulo-freire-dialogue-praxis-and-education/>
- Snow, C. E., & Dibner, K. A. (2016). *Science literacy: Concepts, contexts, and consequences*.
- Somerville MSP, S.-A. (2017). *Minister for Further Education, Higher Education and Science addresses Scottish Parliament on the STEM Education and Training Strategy for Scotland*. Speech / Ministerial Statement. Learning Directorate, Education. Scottish Government. Online. Retrieved from <https://beta.gov.scot/publications/stem-strategy-ministers-speech/>
- Sosu, E. M., & Ellis, S. (2014). *Closing the attainment gap in Scottish Education*. Retrieved from Online: <https://www.jrf.org.uk/sites/default/files/jrf/migrated/files/education-attainment-scotland-full.pdf>
- Spyrou, S. (2011). The limits of children's voices: From authenticity to critical, reflexive representation. *Childhood*, 18(2), 151. doi:10.1177/0907568210387834
- Stange, M., Barry, A., Smyth, J., & Olson, K. (2016). Effects of Smiley Face Scales on Visual Processing of Satisfaction Questions in Web Surveys. *Social Science Computer Review*, 11. doi:10.1177/0894439316674166
- Statistics Solutions. (2017). Table of Critical Values: Pearson Correlation. Retrieved from <http://www.statisticssolutions.com/table-of-critical-values-pearson-correlation/>
- STEM Education Committee. (2016). *STEMEC Report*. Online: Scottish Government Retrieved from <https://www.webarchive.org.uk/wayback/archive/20170115212640/http://www.gov.scot/Topics/Education/Schools/curriculum/STEM/STEMEC/Report/FinalSTEMECReport>
- STEMNET. (2015). STEMNET. Retrieved from www.stemnet.org.uk
- 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. doi:10.1080/03057260903562284
- Straka, G. A. (2004). Informal learning: genealogy, concepts, antagonisms and questions. *Internationales Jahrbuch der Erwachsenenbildung*, 31(1).
- Straka, G. A. (2009). Informal and Implicit Learning: Concepts, Communalities and Differences. *European Journal of Vocational Training*, 48(3), 132-145.
- Strandberg, L. (2007). Vygotsky, a practical friend. *Children in Europe, Rediscovering Vygotsky Special Publication*, 16-18.

- Strange, V., Forest, S., Oakley, A., & Team, t. R. S. (2003). Using research questionnaires with young people in schools: the influence of the social context. *International Journal of Social Research Methodology*, 6(4), 337-346. doi:10.1080/1364557021000024749
- Stucki, I., Pleger, L. E., & Sager, F. (2018). The Making of the Informed Voter: A Split-Ballot Survey on the Use of Scientific Evidence in Direct-Democratic Campaigns. *Swiss Political Science Review*, 1-25. doi:10.1111/spsr.12290
- Tabachnick, B. G., & Fidell, L. S. (2001). *Using Multivariate Statistics* (4th ed.). Boston, United States of America: Allyn and Bacon.
- Tabachnick, B. G., & Fidell, L. S. (2007). *Using Multivariate Statistics* (5th ed.). Boston, United States of America: Pearson Education.
- Tal, T., & Dierking, L. D. (2014). Learning Science in Everyday Life. *Journal of Research in Science Teaching*, 51(3), 251-259. doi:10.1002/tea.21142
- Tharp, R. G., & Gallimore, R. (1988). *Rousing minds to life: Teaching, learning, and schooling in a social context*. Cambridge, United Kingdom: Cambridge University Press.
- The Finnish Science Centre Heureka. (n.d.). About Heureka. Retrieved from The Finnish Science Centre Heureka
- The Scotsman. (2003). Few impressed by the Big Idea. *The Scotsman*. Retrieved from www.scotsman.com website: <https://www.scotsman.com/future-scotland/tech/few-impressed-by-the-big-idea-1-662416>
- Thomaes, S., Bushman, B. J., Orobio de Castro, B., & Stegge, H. (2009). What makes narcissists bloom? A framework for research on the etiology and development of narcissism. *Development and Psychopathology*, 21(4), 1233-1247. doi:10.1017/S0954579409990137
- Tisdall, E. K. M. (2007). *School councils and pupil participation in Scottish secondary schools*. Retrieved from Online: <http://webarchive.nationalarchives.gov.uk/20090724135150/http://scotcons.demonweb.co.uk/education/SCCFinalPupilCouncilsReport.pdf>
- Tisdall, E. K. M. (2013). Effective Contributors: Evaluating the Potential for Children and Young People's Participation in their Own Schooling and Learning. In M. Priestley & G. Biesta (Eds.), *Reinventing the Curriculum: New Trends in Curriculum Policy and Practice* (pp. 117-140). London, United Kingdom: Bloomsbury.
- Tisdall, E. K. M. (2015). Addressing the Challenges of Children and Young People's Participation: Considering Time and Space. In T. Gal & B. F. Duramy (Eds.), *International Perspectives and Empirical Findings on Child Participation* (pp. 381-404). Oxford, United Kingdom: Oxford University Press.
- Tobin, K., & Roth, W.-M. (2006). *Teaching to Learn A View from the Field* (Vol. 4). Rotterdam, The Netherlands: Sense Publishers.

- Toomela, A. (2016). What are Higher Psychological Functions? *Integrative Psychological and Behavioral Science*, 50(1), 91-121. doi:10.1007/s12124-015-9328-0
- Treagust, D. F., Won, M., & Duit, R. (2014). Paradigms in Science Education Research. In N. G. Lederman & S. K. Abell (Eds.), *Handbook of Research on Science Education* (Vol. 2, pp. 3-17). New York, United States of America: Routledge.
- Trinity College Dublin School of Education. (2013). Ethical Approval of Research Proposals. Online: Trinity College Dublin.
- Tudge, J. (1990). Vygotsky, the zone of proximal development, and peer collaboration: Implications for classroom practice. In L. C. Moll (Ed.), *Vygotsky and education: instructional implications and applications of sociohistorical psychology* (pp. 155-174). Cambridge, United Kingdom: Cambridge University Press.
- Tudge, J., & Scrimsher, S. (2003). Lev S. Vygotsky on Education: A Cultural-Historical, Interpersonal, and Individual Approach to Development. In B. J. Zimmerman & D. H. Schunk (Eds.), *Educational Psychology: A Century of Contributions*. (pp. 207-228). Mahwah, New Jersey, United States of America: Lawrence Erlbaum Associates Publishers.
- Twenge, J. M., & Foster, J. D. (2010). Birth Cohort Increases in Narcissistic Personality Traits Among American College Students, 1982–2009. *Social Psychological and Personality Science*, 1(1), 99-106. doi:10.1177/1948550609355719
- United Nations. (1989). *United Nations Convention on the Rights of the Child*. Geneva, Switzerland: United Nations.
- United Nations Committee on the Rights of the Child. (2005). *General Comment No. 7: Implementing child rights in early childhood (No. UN/CRC/C/GC/7)*. Geneva, Switzerland: United Nations, Committee on the Rights of the Child.
- United Nations Committee on the Rights of the Child. (2006). *General Comments of the Committee on the Rights of the Child* (pp. 83). Retrieved from <http://www.unicef-irc.org/publications/pdf/crcgencommen.pdf>
- United Nations Committee on the Rights of the Child. (2009). *General Comment No. 12: The right of the child to be heard (No. UN/CRC/C/GC/12)*. Geneva, Switzerland: United Nations, Committee on the Rights of the Child.
- United Nations Educational, Scientific and Cultural Organisation (UNESCO),. (2017). *Cracking the code: Girls' and women's education in science, technology, engineering and mathematics (STEM)*. Retrieved from Paris, France: <http://unesdoc.unesco.org/images/0025/002534/253479E.pdf>
- Universities Scotland. (2013). *Access All Areas*. Retrieved from Online: <http://www.universities-scotland.ac.uk/index.php?mact=News,cntnt01,detail,0&cntnt01articleid=164&cntnt01returnid=23>

- Valsiner, J., & Veer, R. v. d. (2000). *The Social Mind: Construction of the Idea*. Cambridge, United Kingdom: Cambridge University Press.
- van Oers, B. (2007). In the zone. *Children in Europe, Rediscovering Vygotsky Special Publication*, 14-15.
- Veresov, N. (2004). Zone of proximal development (ZPD): the hidden dimension? In A. Ostern & R. Heila-Ylikallio (Eds.), *Sprak som kultur – brytningar i tid och rum* (Vol. Vol 1, pp. 13-30). Vasa, Finland: ABO Akademi.
- Veresov, N. (2005). Marxist and non-Marxist aspects of the cultural-historical psychology of L.S. Vygotsky. *Outlines. Critical Practice Studies*(1), 31.
- Veresov, N. (2010a). Introducing cultural historical theory: main concepts and principles of genetic research methodology. *Cultural-Historical Psychology*(4), 83-90.
- Veresov, N. (2010b). Reading 'Thinking and Speech' (Vygotsky) Part I. Online: Vimeo.
- Veresov, N. (2010c). Reading 'Thinking and Speech' (Vygotsky) Part II. Online: Vimeo.
- Verhellen, E. (2001). Facilitating Children's Rights in Education: Expectations and demands on teachers and parents. In S. N. Hart, C. P. Cohen, M. F. Erickson, & M. Flekkoy (Eds.), *Children's Rights in Education* (pp. 179-190). London, United Kingdom: Jessica Kingsley.
- Vygotsky, L. S. (1934/1962). *Thought and Language* (E. Hanfmann, G. Vakar, & A. Kozulin Eds. 2012 ed.). Cambridge, Massachusetts, United States of America: MIT Press.
- Vygotsky, L. S. (1978). *Mind in Society: the Development of Higher Psychological Functions*. Cambridge, Massachusetts, United States of America: Harvard University Press.
- Vygotsky, L. S., Rieber, R. W., & Carton, A. S. (1987). *The collected works of L. S. Vygotsky, Vol. 1: Problems of general psychology*. New York, United States of America: Plenum Press.
- Wall, K., Higgins, S., Hall, E., & Woolner, P. (2013). 'That's not quite the way we see it': the epistemological challenge of visual data. *International Journal of Research & Method in Education*, 36(1), 3-22. doi:10.1080/1743727X.2012.730278
- Wallace, C. S., & Priestley, M. R. (2017). Secondary science teachers as curriculum makers: Mapping and designing Scotland's new Curriculum for Excellence. *Journal of Research in Science Teaching*, 54(3), 324-349. doi:10.1002/tea.21346
- Warford, M. K. (2011). The zone of proximal teacher development. *Teaching and Teacher Education*, 27(2), 252-258. doi:10.1016/j.tate.2010.08.008
- Watson, A. (2016). The Big Idea: Scotland's millenium project doomed to fail. *The Scotsman*. Retrieved from www.scotsman.com website: <https://www.scotsman.com/lifestyle/the-big-idea-scotland-s-millennium-project-doomed-to-fail-1-4198151>

- Weaver, R., Hanks, J., & Staiano, S. (2017). *Developing a Scottish STEM Evidence Base: Final Report for Skills Development Scotland*. Retrieved from Online:
<http://www.gov.scot/Resource/0052/00526538.pdf>
- Weedon, E. (2014). *Widening participation to higher education of under-represented groups in Scotland: The challenges of using performance indicators*. Retrieved from Edinburgh, Scotland:
https://www.centreonconstitutionalchange.ac.uk/sites/default/files/papers/workingpaper1_performanceindicators_creid.pdf
- Weedon, E. (2017). The construction of under-representation in UK and Swedish higher education: Implications for disabled students. *Education, Citizenship and Social Justice*, 12(1), 75-88. doi:10.1177/1746197916683470
- Wellcome Trust. (2012). Science Learning +. Retrieved from
<http://www.informalscience.org/projects/funding/science-learning-plus>
- Wellcome Trust. (2013). *Wellcome Trust Monitor Wave 2* (pp. 143). Retrieved from
<https://wellcome.ac.uk/sites/default/files/monitor-wave2-full-wellcome-may13.pdf>
- Welty, E., & Lundy, L. (2013). A children's rights-based approach to involving children in decision making. *Journal of Science Communication*, 12(03). Retrieved from
<http://jcom.sissa.it/sites/default/files/documents/JCOM1203%282013%29C02.pdf>
- Werquin, P. (2010). *Recognising non-formal and informal learning: outcomes, policies and practices*. Paris, France: Organisation for Economic Co-operation and Development.
- Wertsch, J. V. (1985a). Introduction. In J. V. Wertsch (Ed.), *Culture, communication, and cognition: Vygotskian perspectives* (pp. 1-18). Cambridge, United Kingdom: Cambridge University Press.
- Wertsch, J. V. (1985b). *Vygotsky and the Social Formation of Mind*. Cambridge, Massachusetts, United States of America: Harvard University Press.
- Wertsch, J. V., & Stone, C. A. (1985). The concept of internalization in Vygotsky's account of the genesis of higher mental functions. In J. V. Wertsch (Ed.), *Culture, communication, and cognition: Vygotskian perspectives* (pp. 162-182). Cambridge, United Kingdom: Cambridge University Press.
- Wiles, R., Crow, G., Heath, S., & Charles, V. (2008). The Management of Confidentiality and Anonymity in Social Research. *International Journal of Social Research Methodology*, 11(5), 417-428. doi:10.1080/13645570701622231
- William, D. (2011). *Embedded formative assessment*. Bloomington, Indiana, United States of America: Bloomington, Ind. : Solution Tree Press.
- Wongpakaran, N., Wongpakaran, T., Wedding, D., & Gwet, K. L. (2013). A comparison of Cohen's Kappa and Gwet's AC1 when calculating inter-rater reliability coefficients: a

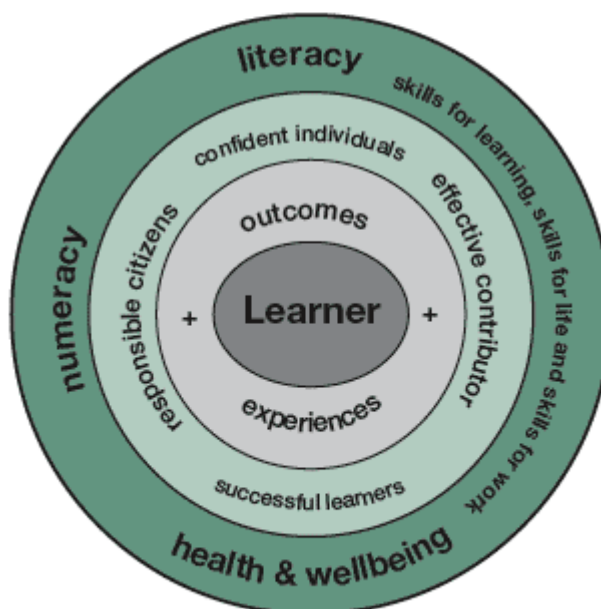
- study conducted with personality disorder samples. *BMC Medical Research Methodology*, 13(1), 1-7.
- Yoon, S. A., Elinich, K., Wang, J., Van Schooneveld, J. B., & Anderson, E. (2013). Scaffolding Informal Learning in Science Museums: How Much Is Too Much? *Science Education*, 97(6), 848-877.
- Yudina, E. (2007). Lev Vygotsky and his cultural-historical approach. *Children in Europe, Rediscovering Vygotsky Special Publication*, 3-4.
- Zaretskii, V. K. (2009). The Zone of Proximal Development: What Vygotsky Did Not Have Time to Write. *Journal of Russian & East European Psychology*, 47(6), 70-93.
doi:10.2753/RPO1061-0405470604
- Zavershneva, E. I. (2012). Investigating L. S. Vygotsky's Manuscript "The Historical Meaning of the Crisis in Psychology". *Journal of Russian & East European Psychology*, 50(4), 42-63.
doi:10.2753/RPO1061-0405500402
- Zuckerman, G. (2007). Child-Adult Interaction That Creates a Zone of Proximal Development. *Journal of Russian & East European Psychology*, 45(3), 43-69. doi:10.2753/RPO1061-0405450302

Appendices

Appendix 1 Extract from schematic guide to curriculum framework for curriculum planners

The curriculum: ‘the totality of all that is planned for children and young people throughout their education’

- Ethos and life of the school as a community
- Curriculum areas and subjects
- Interdisciplinary learning
- Opportunities for personal achievement



Appendix 2 Record of PVG Scheme membership

Disclosure type	Date
Enhanced Disclosure	May 2009
Basic Disclosure	December 2012
Disclosure and PVG Scheme Membership	February 2016



**Application to Undertake Research in
Perth and Kinross Council's
Education and Children's Services**

Perth and Kinross Council generally encourages and supports educational research in schools and other educational establishments in Perth and Kinross.

Approval in principle is required from Education and Children's Services Senior Management for all research and is subject to the standard conditions listed below (further conditions may also be applied as part of the approval process on a case by case basis). Researchers are required to complete the application below and submit this to the Performance and Scrutiny Team to apply for permission to undertake their research. Every effort will be made to convey a timeous decision to researchers regarding their application.

Where approval in principle has been granted by Education and Children's Services Senior Management, the final decision to permit the research in their establishment lies with the Headteacher/Head of Establishment. The Headteacher/Head of Establishment will be responsible for ensuring, where relevant, the following conditions are met. Headteachers may also require to consult with the Parent Council if the project specifically relates to an area where they have a statutory function.

Standard Conditions of Approval

1. There will be no unsupervised contact with children/young people or access to confidential information held by Perth and Kinross Council. *(In exceptional circumstances unsupervised contact with children/young people & access to confidential information may be approved where there is PVG Scheme membership & appropriate checks have been undertaken.)*
2. Researchers must obtain appropriate parental/carers permissions where required. The requirement for parental/carers permission must be agreed with, and facilitated by, the Headteachers/Heads of Establishment prior to the research starting.
3. Strict observation of confidentiality must be respected and in particular the researcher must comply with the terms of the Data Protection Act. The researcher must be able to

satisfy the Council that all research will be carried out in a manner which complies with both the Data Protection Act and any ethical research standards relevant to the research being carried out.

4. The methodology involved in conducting the research does not in any way impair the educational process or health and wellbeing of children/young people.
5. The involvement of all Council staff with research projects is understood to be entirely voluntary.
6. All relevant details of the research project are disclosed on the attached application form.
7. No disclosure of the findings of the research project is to take place before a date specified at the outset of the project, unless with the specific permission of the Executive Director, Education and Children's Services.
8. A copy of the findings of the research project should be sent to the Performance and Scrutiny Team, free of charge, on completion of the project.

Please complete this application form to request approval in principle for your research from Education and Children's Services Senior Management.

Do you require unsupervised contact with children/young people or access to confidential information in order to undertake your research?

If you have answered yes then further information regarding your PVG Scheme membership is required. Please contact the Performance and Scrutiny Team on (01738) 476349 or email tmccconnell@pkc.gov.uk.

Appendix 4 Information Leaflets and Consent Forms

Initial leaflets

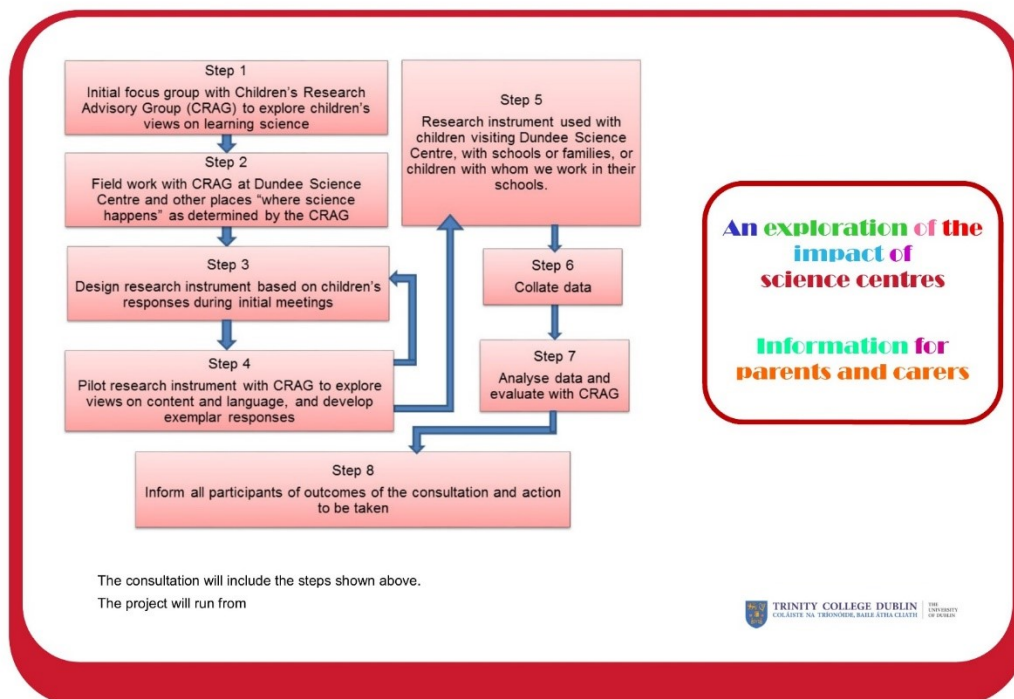
Parents and carers

The leaflet for parents and carers was amended for circulation to school staff.

Children invited to participate in the CRAG

Additional leaflets

Children participating in the CRAG



Aim

The aim of this project is to consult with children to provide a clear, evidence-based understanding of what children think about learning science outside school.

Background to the project

Science centres worldwide work with people of all ages to engage them with sciences, technologies and engineering in the world around them.

Children and young people often visit science centres with their families, or as part of school trips. We also work with children in their schools. We ask the children and their teachers to evaluate the experience they have. However, we ask them what they think by asking them the questions we have thought of, about things we think are important. There is very little research worldwide to understand what children think about learning science outside school, in science centres. Some aspects we would like to explore include whether or not learning in science centres is like learning in school, and whether or not it should be.

In Scotland, we are in the process of implementation of curriculum for excellence. This provides a framework for recognising learning where it happens, meeting the needs of individuals and recognising that each child has an individual learning journey.

Dundee Science Centre Science Learning Institute is part of the learning that happens beyond the classroom. The outcomes of this research will make a difference to how we work with children and young people.

Science Gallery Dublin is also involved in this research. The outcomes of this project will be shared with them for consideration.

Consultation with children

I am a postgraduate researcher, based at Trinity College Dublin. I am a qualified secondary teacher of Physics and Science, GTCS registered and Disclosure Scotland PVG checked.

I will invite group of children from one school in the first instance, to work with me and the team at Dundee Science Centre to produce a questionnaire for completion by a large number of children. These will be children who visit Dundee Science Centre with families or with schools, or whom we work with on outreach (for example in schools and community centres).

The group of children is called a Children's Research Advisory Group (CRAG).

The CRAG will be invited to talk about learning in science outside school. They will have the opportunity to visit Dundee Science Centre and other places where science happens, outside school. These visits will be determined by the children's interests and views, as well as feasibility. For example, we will take into account geographical location, and health and safety considerations.

The children will gain experience in designing a research instrument for other children, as well as interpreting what we find.

Your right to withdraw consent

You can stop your child taking part at any time. You do not have to say why. Your child can also choose to stop taking part at any time. He or she does not have to give a reason or explanation.

Contact information

My name is Lauren Boath.

My supervisor, Professor Colette Murphy of the School of Education at Trinity College Dublin can be contacted on



An exploration of the impact of science centres

Consent form (Children's Research Advisory Group)

Name of your child:

Where we talk about "my child" or "your child", we mean a child for whom you have parental responsibility.

Please
initial in
the box

I have read the information sheet and I have had a chance to think about the information.

☐

I understand that it is ok for me to stop my child taking part at any time. I do not have to say why.

☐

I understand that the researchers will be recording notes and discussions, when my child is working with other children or adults on this project.

☐

I understand that the researchers will audio record my child's voice when he/she is talking to other children and adults for the project.

☐

I understand that the researchers might include quotes from my child's written, verbal or artwork based input in their reports, when they are talking at conferences in research papers and in PhD thesis chapters. I give my permission for them to do this. They will not use my child's name. All quotes, written work or artwork will be anonymous.

☐

I agree to allow my child to attend the following meetings as part of the Children's Research Advisory Group (CRAG):

1. an initial meeting in his / her own school

☐

2. three meetings (field work) in places like Dundee Science Centre or other places where science happens outside school

☐

3. a meeting where we design a "questionnaire" for other children to use, in my child's school

☐

4. a meeting to discuss the findings from the questionnaire used by other children, in another venue (which the researchers will tell me about nearer the time)

☐

I understand that my child will be accompanied by a member of staff from the school for all meetings which do not take place in the school. I will be fully informed of all travel arrangements.

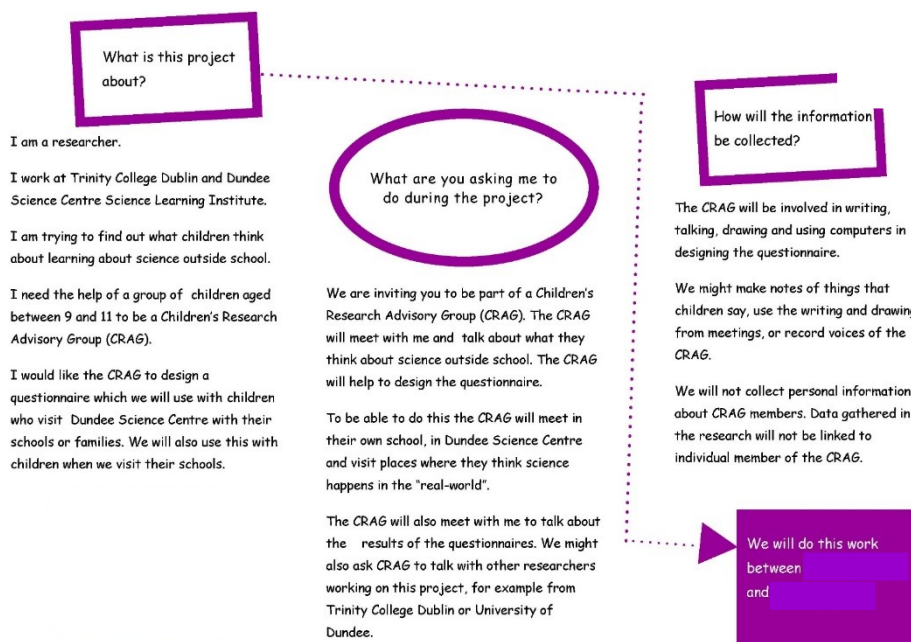
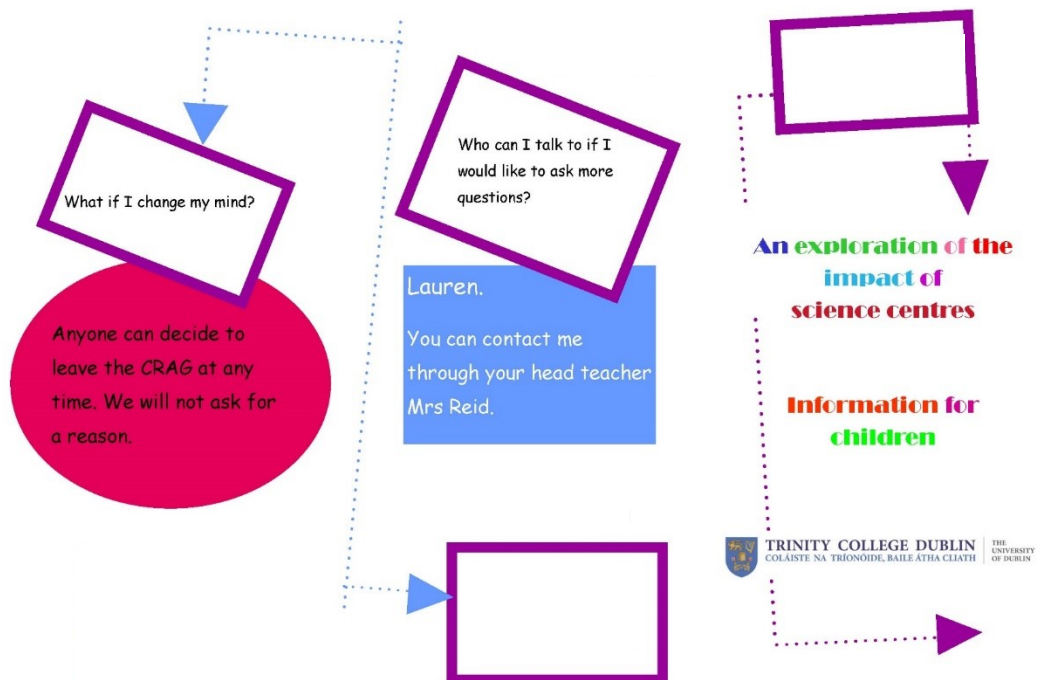
☐

I agree for my child to take part in the above study

Name

Signature

Date





TRINITY COLLEGE DUBLIN | THE UNIVERSITY OF DUBLIN
CO. AESTÉ NA TRIONÓIDE BAILE ÁTHA CLIAITH

An exploration of the impact of science centres

Participant ID

Please put your initials in the box

I have read the information sheet with Lauren and I have had a chance to think about the information. I have asked all the questions I wanted to.

☐

I understand that it is ok for me to stop taking part at any time. I do not have to say why.

☐

I understand that the researchers will be recording my notes and discussions when I am talking to other children and adults for the project. The researchers will tell me when they are going to do this.

☐

I understand that the researchers may audio record my voice when I am talking to other children and adults for the project. The researchers will tell me when they are recording.

☐

I understand that the researchers might like to use something that I say (written, verbal or from my artwork) in their reports, when they are talking at conferences or in research papers. I give my permission for them to do this. They will not use my name - anything that I say or write, or my artwork, will be anonymous.

☐

Please put your initials in the box

I agree to attend the following, unless I decide not to later on:

☐

1. an initial meeting in my own school

☐

2. three visits (field work) in places like Dundee Science Centre or other places where science happens outside school

☐

3. two meetings in my own school where we design a questionnaire for other children to use, and we test out the questionnaire to see how well it works

☐

4. a meeting where we discuss the findings from the questionnaire used by other children, in another venue (which the researchers will tell me about nearer the time). This will probably not be until I am in primary 7.

☐

I understand that I will be accompanied by a member of staff from my school for all meetings which do not take place in my school. I will be fully informed of all travel arrangements.

I agree to take part in the above study

Name

Signature

Date



Consent form

Children's Research Advisory Group (CRAG)

Participant ID

Please
put your
initials in
the box

I have talked about the project with Lauren and I have had a chance to think about the information. I have asked all the questions I wanted to. ☐

I understand that it is ok for me to stop taking part at any time. I do not have to say why. ☐

I understand that the researchers will be recording my voice, notes and discussions when I am talking to other children and adults for the project. The researchers will tell me when they are recording. ☐

I understand that the researchers might like to use something that I say (written, verbal or from my artwork) in their reports, when they are talking at conferences or in research papers. I give my permission for them to do this. They will not use my name - anything that I say or write, or my artwork, will be anonymous. ☐

I agree to attend the following, unless I decide not to later on:

1. a meeting in _____, in my school to find out about what has happened with the project since we last met together. ☐

2. a meeting in _____, either in my school or at the University of Dundee, to do hands-on science and to learn more about my rights as a child. At this meeting we will also start talking about what we think about what we found from the questionnaire when it was used by other children. ☐

3. a meeting at my school in _____ where we talk about what we think about what we found from the questionnaire when it was used by other children. ☐

I understand I will be fully informed about arrangements for meetings including travel arrangements for meetings which take place outside school. ☐

I agree to continue to take part in this research study

Name

Signature

Date

Appendix 5 Profile of the primary school hosting the CRAG

The primary school hosting the CRAG has a roll of 133 children in nursery and primary 1 – 7. Seven miles from the centre of the nearest city, it is defined as an ‘accessible rural’ area, that is, a settlement with fewer than 3000 people and within a 30-minute drive time of a settlement of 10000 or more (SG, 2014b). The geographical area within which the school is located is ranked 4907 in the Scottish Index of Multiple Deprivation (SG, 2013c), with a scale on which 6505 is the least-deprived zone in Scotland (SG, 2013b). It is one of a cluster of 16 schools associated with a city-based high school; the majority of the children progress to this secondary school. However, there are a number of other schools that are geographically closer, that children may attend for secondary school.

Appendix 6 Schedule of CRAG meetings

CRAG meeting	Date and time of meeting	Venue
1	25/04 (participants' P5) 1.15 pm – 3.15 pm	Primary School
2	01/05 (participants' P5) 10.30 am – 2.00 pm	Dundee Science Centre
3	10/06 (participants' P5) 10.00 am – 12.30 pm	Institute for Medical Sciences and Technology, Dundee
4	16/06 (participants' P5) 10.30 am – 12.30 pm	Primary School
5	05/10 (participants' P6) 10.30 am – 12.30 pm	Primary School
6	07/03 (participants' P7) 1.15 pm – 2.15 pm	Primary School
7	17/03 (participants' P7) 10.00 am – 2.30 pm	University of Dundee
8	30/05 (participants' P7) 11.00 am – 2.30 pm	Primary School
9	15/06 (participants' P7) 11.00 am – 2.30 pm	Primary School
10	16/06 (participants' P7) 11.00 am – 2.30 pm	Primary School

Appendix 7 CRAG Badges

Note that the chosen names are pseudonyms



Appendix 8 CRAG Badges (updated)

Note that the names chosen are pseudonyms



Appendix 9 Activities to enable access to information to inform views

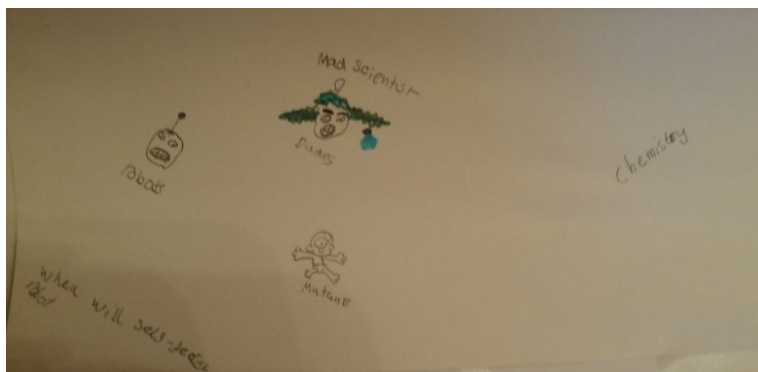
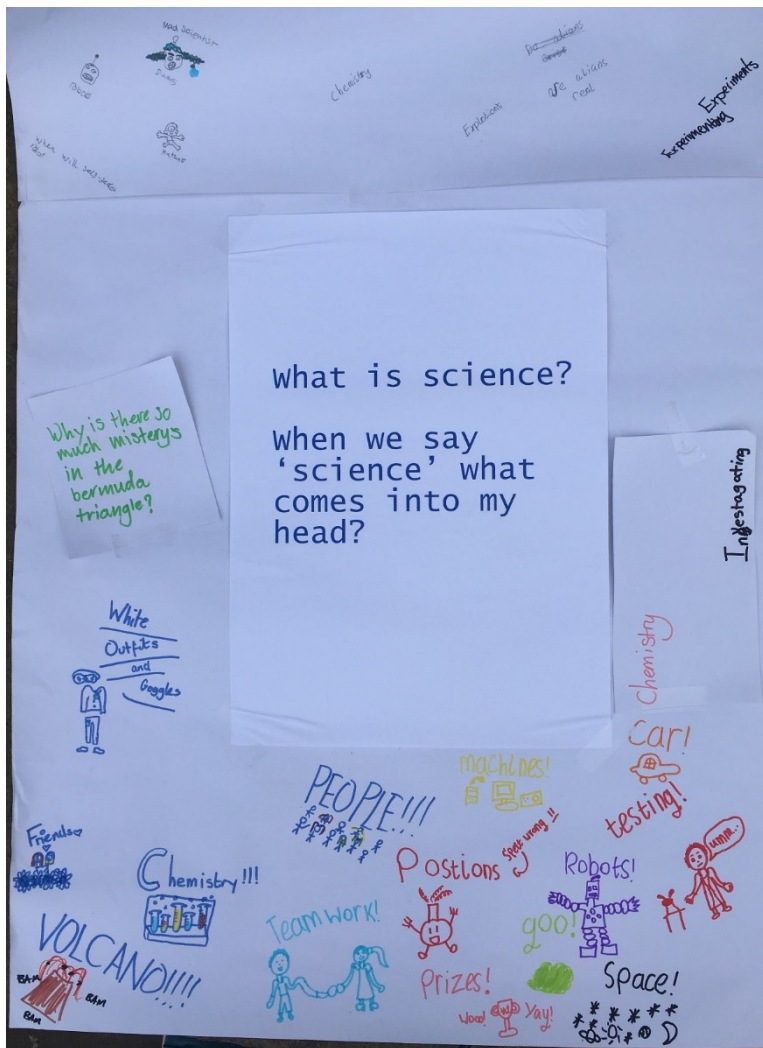
'What is science?' (CRAG meeting 1)

In the first CRAG meeting, the question was posed: what is science? with the sub-question: when we say science, what comes into your head? The questions were discussed, and each was written in colour on an A2 sheet. A number of images and artefacts, chosen by a 10-year-old, were available for the CRAG; this was explained to participants as something that researchers do: consider data, objects and information for ideas about the research and to develop their thinking.

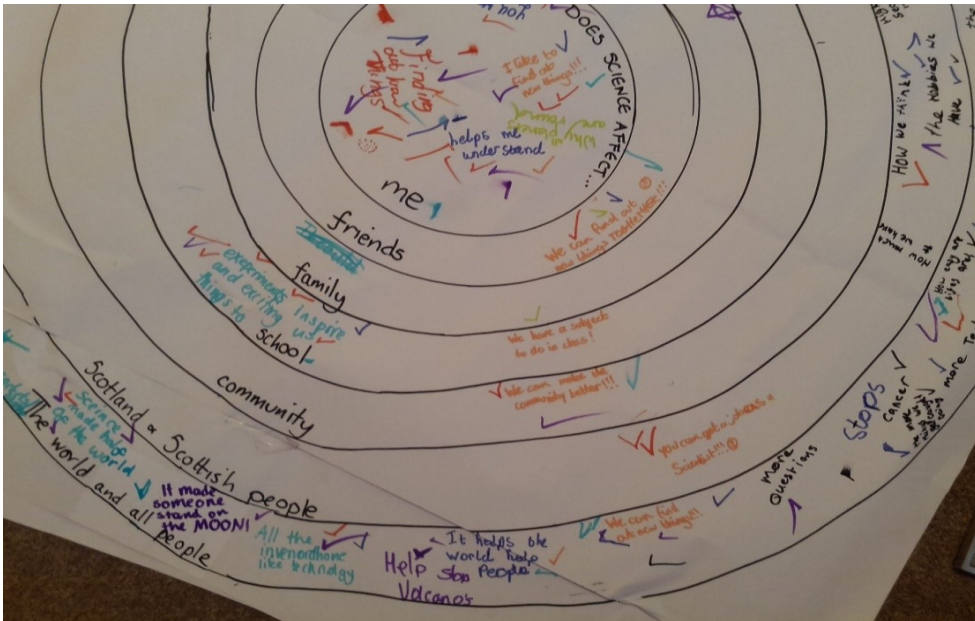
Objects: globe, banana, sunglasses, battery, bath bombs, pot plants, science equipment such as test tubes, pipettes.

Images: lamp, variety of medicines and tablets, car, jet engine, hospital heart rate monitor screen, bicycle, radar screen, solar panels, bridge over a river, Pelamis wave energy converter, radiator, Sony PSP, array of smart phones and tablets, Xbox 360 Kinect, wind turbine, foetal ultrasound scan image.

'What is science?' (CRAG meeting 1) exemplar responses

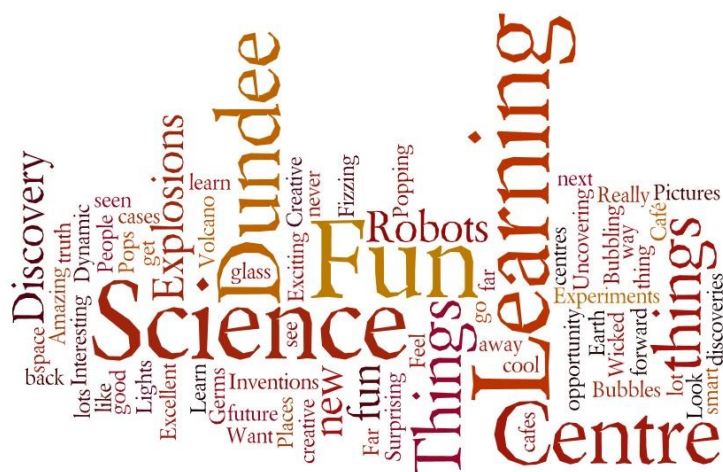
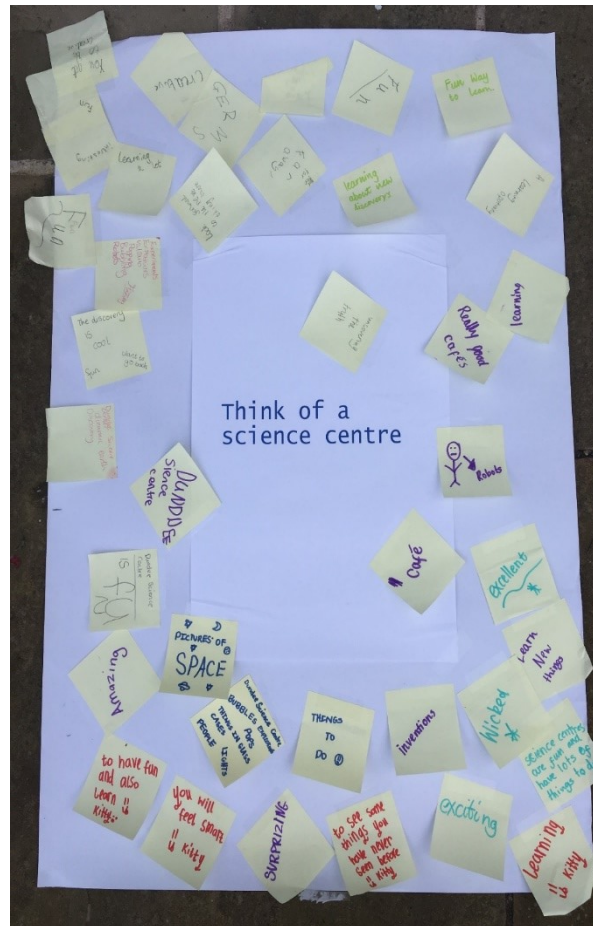


‘How does science affect...?’ (Crag meeting 1) concentric circles



'Think of a science centre' (CRAG meeting 1)

The children were invited to think about a science centre, and using sticky notes, capture their thoughts on a flipchart sheet. The 55 words or phrases were converted into a Wordle.



2)

activities, to avoid appearing in a supervisory or teacher role.

meeting room space.

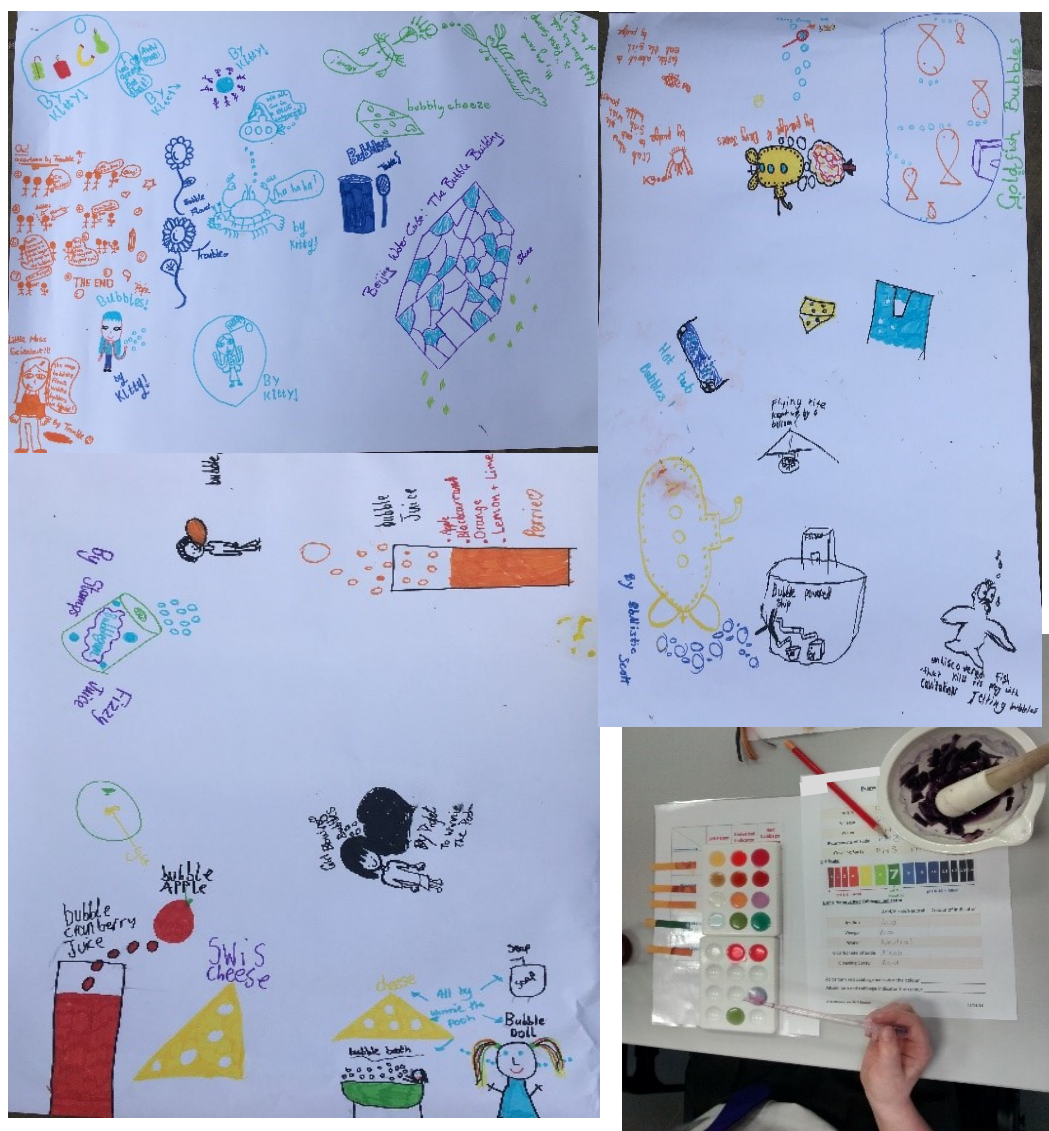
boys on the 'boy' poster response.



'Visiting places where science happens' (CRAGs 3 and 7)

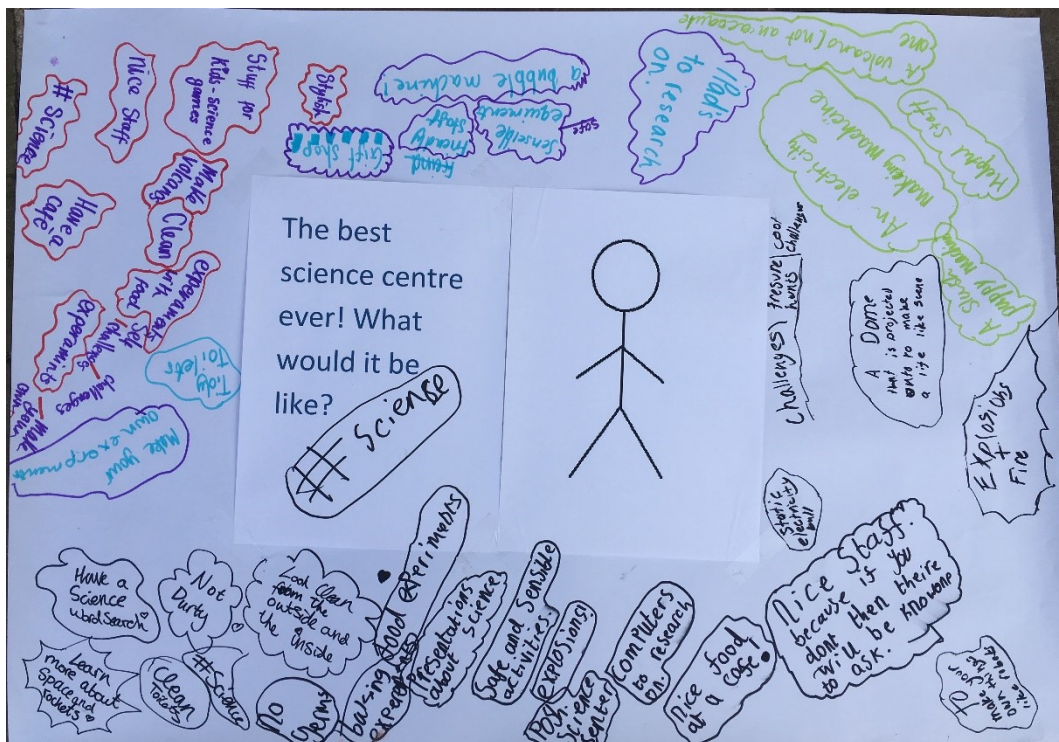
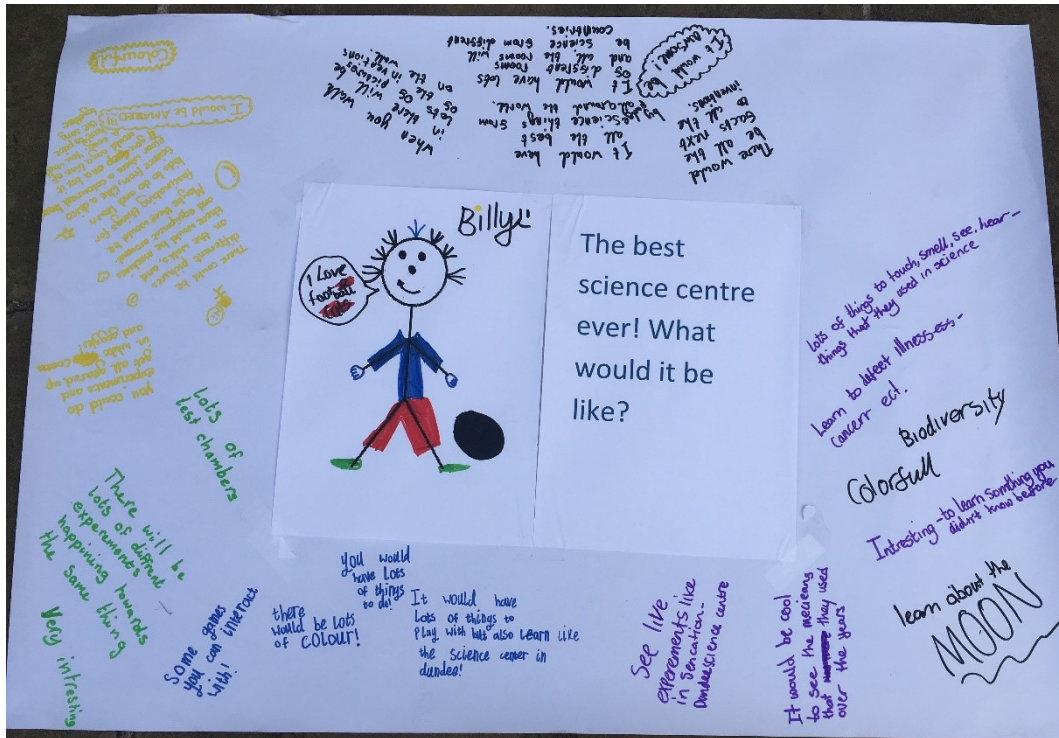
The CRAG considered and suggested places 'where science happens', and subsequently visited the Institute for Medical Science and Technology (IMSAT), an interdisciplinary institute linking physics, engineering, mathematicians and life scientists with clinicians and health service providers. This joint enterprise between the Universities of Dundee and St Andrews is located in the Dundee Medipark next to Ninewells Hospital and Medical School (IMSAT, 2016). Accompanied by my research colleague from Trinity College Dublin and my student colleague, the children heard about cutting-edge work to link physics and medicine and visited laboratories and workshops people were working with medical imaging, lasers and designing and making new tools and instruments for use in medicine.

The CRAG also visited the University of Dundee, working with postgraduate student teachers on hands-on science activities designed by the students.



'The best science centre ever?' (CRAG meeting 3)

Whilst at IMSAT, the CRAG was invited to consider the ‘best science centre ever’ capturing their thinking through scribbling or drawing on A2 flipcharts.



Appendix 10 Transcript of introductory video for research participants

[Lauren]: My name is Lauren. I am a researcher at a university in Ireland.

[image of TCD logo & image of Ireland on map with Great Britain & NI]

I am interested in finding out what you think about science places you have visited, or people or groups who come to your school to do science with you.

[image with text reading

what you think about

- science places you have visited
- people or group who come to your school to do science with you]

[Grace]: I am Grace and I have been helping with this research. 11 children from Perth and Kinross have been advising Lauren on how to do her research, to get it right for children. They are the Children's Research Advisory Group.

[image with text reading

Children's Research Advisory Group]

About 50 other children have helped too.

We'd like you to answer some questions for us.

[image of questionnaire front page]

It is anonymous, which means that no-one will be able to match the questionnaire back to you. The school will just send them back to Lauren.

We're asking about science things you have done outside lessons. This might be: visiting a science centre with your school, or your family in Dundee, Glasgow or somewhere else; going to a science festival like the one in Edinburgh; or you might have had science people work with you in your school.

[image with text reading

- visiting a science centre
- going to a science festival
- having scientists work with you in school]

If there are any questions you don't want to answer, just skip them.

[Lauren]: And thanks! By doing this, you're helping us to understand how to make science experiences better for children.

Appendix 11 Questionnaire issued for use with research participants (version 11)

TRINITY COLLEGE DUBLIN
COLLAISTE NA TRIONDAIR, BAILE KILBA CLÉIRÍ

THE UNIVERSITY OF JEREMY

Science

This questionnaire is about what you think about your science experiences.

Please watch the short video.

These experiences might be visits to

- a science centre
- an observatory
- a science festival
- a nature reserve

Or, you might have had someone visit your school to do science with you.

You may have done one or more of these things. You might have done them on a school trip or outside school.

You might have done these things this year, last year or when you were younger.

Your opinions will help make science experiences better. Remember, there are no right or wrong answers. No-one will know what you said in the questionnaire. You do not need to tell us your name.

© LBoath 2018

PLEASE TICK ONE

I'M A GIRL ☐ I'M A BOY ☐

Science

HOW OLD ARE YOU?

I AM YEARS OLD

PLEASE WRITE A NUMBER IN THE BOX

I HAVE HAD A SCIENCE EXPERIENCE

☐ THIS YEAR ☐ LAST YEAR ☐ EARLIER

PLEASE TICK ONE, TWO OR THREE BOXES

I HAVE HAD A SCIENCE EXPERIENCE

WITH MY SCHOOL ☐ NOT WITH MY SCHOOL ☐

PLEASE TICK ONE OR BOTH

© LBoath 2018

PLEASE ANSWER ALL THREE QUESTIONS

1. Do you like learning science in school?

TICK ONE BOX

yes – a lot ☐
yes – a little ☐
no ☐
I'm not really sure what science we do in school ☐

PLEASE WRITE YOUR NAME

2. Which of these science things do you enjoy?

TICK AS MANY BOXES AS YOU LIKE

watching science TV programmes ☐
doing experiments with science kits ☐
nature walks ☐
visiting places to do with science ☐
reading science magazines ☐
other (please tell us about these on line below) ☐

3. How good do you think you are at science?

very good ☐
ok ☐
not good ☐

TICK ONE BOX

© LBoath 2018

4. What would you say about your science experience or experiences? We're asking about experiences outside your normal lessons.

TICK ONE BOX ON EACH LINE

My experience... Yes Not sure No

...was interesting ☐ ☐ ☐

...was fun ☐ ☐ ☐

...made it easy for me to learn ☐ ☐ ☐

...made me think ☐ ☐ ☐

...increased my curiosity about things ☐ ☐ ☐

...increased my understanding of the world around me ☐ ☐ ☐

...has shown me how science affects our way of living ☐ ☐ ☐

...helped me to understand Scotland and its place in the world ☐ ☐ ☐

...helped me think about environmental, technological and scientific issues ☐ ☐ ☐

...made me think about jobs ☐ ☐ ☐

...encouraged me to be creative ☐ ☐ ☐

...involved exploring new things ☐ ☐ ☐

...gave me a chance to use modern technologies ☐ ☐ ☐

© LBoath 2018

SCIENCE EXPERIENCES MAKE ME FEEL...

WE ASKED SOME CHILDREN
HOW A SCIENCE EXPERIENCE MAKES THEM
FEEL ABOUT SCIENCE

HERE IS SOME OF THEM THEY TOLD US

EXCITED AND CRAZY! I
CAN'T WAIT TO SEE ALL
THE INTERESTING AND
SURPRISING THINGS TO
DO

Cory said

AMAZED! IT MAKES ME
FEEL THERE IS A LOT
MORE TO THINK ABOUT
AND LIKE I KNOW A
LOT MORE

Jo said

Rowan said

IT MAKES ME FEEL
LIKE SCIENCE IS
SCIENTIST! IT MAKES ME
HAPPY AND MAKES ME WANT
TO EXPLORE MORE
SCIENCE

IT MAKES ME FEEL
LIKE SCIENCE IS
MORE IMPORTANT,
I WANT TO DO
MORE SCIENCE

IT MAKES ME FEEL EXCITED
FOR EXPERIMENTING
AND MORE CREATIVE ON
EXPERIMENTS

Pat said

Robyn said

IT GIVES YOU THE
IDEAL. IF YOU WANT TO
BE AN INVENTOR, I
THINK THIS WILL HELP
ME WITH GROWING UP.

HOW DO YOUR SCIENCE EXPERIENCES MAKE YOU FEEL ABOUT SCIENCE?
TELL US!

I think science experiences should...

WE SHOULD SOME CHALLENGE
HOW SCIENCE EXPERIENCES CAN HELP THEM LEARN
 HERE'S SOME OF THE THINGS THEY SAID

READ WHAT THEY SAID AND **TELL US**
 THE ONE YOU AGREE WITH

MacKenzie said

SCIENCE PLAYS A BIG ROLE IN OUR LIVES, ALTHOUGH WITH COMPUTERS AND VIDEOS

Sam said

THERE SHOULD BE DIFFERENT EXHIBITIONS AND DIFFERENT ROOMS WITH SCIENCE FROM DIFFERENT COUNTRIES AND ALL THE BEST SCIENCE THINGS FROM AROUND THE WORLD.

Nicky said

COMPUTERS WITH SCIENCE GAMES AND ACTIVITIES WOULD BE BETTER LEARNING WE SHOULD ALSO BE ABLE TO RESEARCH TO HELP OUR LEARNING

Alex said

COOL CHALLENGES AND TREASURE HUNTS WOULD HELP PLANTS WOULD HELP US LEARN WE SHOULD BE ABLE TO MAKE UP OUR OWN EXPERIMENTS AND LOTS OF DIFFERENT EXPERIMENTS TOWARDS THE SAME THINGS

Charlie said

THERE SHOULD BE MORE FOR US TO SEE AND DO AND THEY SHOULD LET US DO MORE LOTS OF THINGS TO SEE, TRY, TOUCH AND SMELL WOULD HELP US LEARN

Romni said

THERE SHOULD BE LOTS OF FUN THINGS TO INTERACT AND SHOULD BE MORE SCIENCE CENTRE FOR ALWAYS WE SHOULD BE ABLE TO PICK UP THE ORBITAL RING, POWER OR DO ACTIVITIES

Jamie said

I THINK THERE SHOULD BE MORE CHALLENGES AND TREASURE HUNTS AS WELL AS OUR OWN EXPERIMENTS AND LOTS OF DIFFERENT EXPERIMENTS TOWARDS THE SAME THINGS

Ash said

I WOULD LEARN BETTER IF THERE WERE MORE INFORMATION NEXT TO INVENTIONS AND EXHIBITS, LOTS OF PICTURES OF INVENTIONS ON THE WALLS, THEY NEED TO BE KING STAFF WITH HELP US, AND EXPLAIN THINGS BETTER TO HELP US LEARN, THE STAFF MUST BE ABLE TO ANSWER OUR QUESTIONS.

How can science experiences help YOU learn? WRITE WHAT YOU THINK.

I think science experiences should...

WE ASKED SOME CHILDREN
WHAT SCIENCE EXPERIENCES COULD
DO TO HELP THEM ENJOY SCIENCE
MORE

HERE'S SOME OF WHAT THEY THOUGHT

READ WHAT THEY THOUGHT AND
TEACH THE OTHERS YOU KNOW BETTER

INSTEAD OF JUST TALKING
AND LISTENING THERE
SHOULD BE MORE KIDS
ACTIVELY PLAYING WITH
HAVE TEST TUBE STATIONS
LIVED ACTIVITIES SO YOU
HAVE TO THINK QUICKLY AND
GET THE ACTIVITY DONE IN
TIME

Andie said

"IPADS, IPODS
TABLETS WE CAN
USE THESE WE CAN
MAKE IT MORE
INTERESTING BY
HAVING MORE
GAMES AND NUMBER
TECHNOLOGIES"

Jordan said

"I WOULD LIKE TO HAVE SOME ON AN
ADVENTURE WALK OR GO EXPLORING
THERE SHOULD BE SCIENCE THAT HAPPENS
ALL OVER THE WORLD"

Jody said

"I WOULD ENJOY IT MORE
ABOUT SCIENCE BRACKETS
TO HELP US LEARN PUPPET
SHOWS ARE INTERACTIVE
THINGS"

Theo said

"HELPFUL STUFF CAN HELP
US LEARN MORE THEY
CAN SHOW HOW THEY
WOULD EXPLORE AND GIVE US
MORE GUIDES"

Lou said

"LEARNING LOTS WOULD HELP ME
ENJOY IT MORE I WOULD LIKE
TO HAVE MORE TO DO AND LEARN
WITH LOTS TO EXPLORE THERE
SHOULD BE LOTS OF INVENTIONS
TO FIND OUT ABOUT."

Billie said

"—WOULD ENJOY IT
IF THERE WERE
MORE FUN THINGS AND
LET US DO MORE
STUFF AND MORE
ON OUR OWN
EXPERIMENTS AND DO
MORE EXPERIMENTS"

Cameron said

"IT IS MORE ENJOYABLE IF
- THERE IS MORE COLOUR AND -
THE PLACE IS CLEAN AND TIDY -
LOOKS COOL AND IS STYLISH,
INSIDE AND OUTSIDE"

WHAT COULD SCIENCE EXPERIENCES DO TO HELP **You** ENJOY SCIENCE MORE?
WRITE WHAT **YOU** THINK.

IS THERE ANYTHING ELSE YOU WOULD LIKE TO TELL US ABOUT SCIENCE OR SCIENCE EXPERIENCES? WRITE OR DRAW!

THANK YOU
for telling us what you think.



© LBooth © LBooth 2018

Appendix 12 Reviewing research instruments (CRAG meeting 2)

Views on *ROSE* (relevance of science education) survey (Schreiner & Sjoberg, 2004; Sjoberg & Schreiner, 2010). Note: children didn't understand the title "relevance of science education" and requested an explanation of what the survey was about.

Positive	Things which could be improved
I like the book (NB. the survey was in spiral bound book)	More colour A bit more colourful Not much colour More colour Not enough colour Not colourful Not very colourful It could be more colourful and bright Don't really think it is colourful
I like the boxes that you tick	I think it is a bit dull It's a bit dull and boring looking It is a bit boring Not many pictures More pictures More exciting pictures Boring More interesting cover
	A bit too much questions Less questions, it is a bit too many Too many questions Less questions It is a bit adulty for children It's a bit like an adult survey The writing needs to be bigger

Views on Braintastic survey (Murphy et al., 2010)

Note: children were presented with the survey as hard copy rather than in the online format for which it was designed which may have contributed to some of the comments about size and readability.

Positive	Things which could be improved
Like the colour of the writing	Use different colours (not just green!)
Very colourful and bright	Too adultish make it more colourful
I like how they put pictures in	There could be more pics because there is a lot of
Like the pics	writing and not much pictures
Like the pictures	More pics
	The only picture I see is really small
	More pictures
Good info	A bit too complicated
Good questions for England and	Less questions
Wales, there should be a quiz for	Lots of fancy words which is bad because people will not
Scots and Ireland	understand
	More options of answers
Awesome	I don't think we could answer these, they are really
	small
	Bigger writing x 2
	It's a tiny bit small
Fantastic	
Fabulous	

Views on draft questionnaire version 1

Note: Pages 1, 6 and 7 of this draft survey were presented in a proposed format to garner CRAG's views on this format. Pages 2-5 included plain text only, for comment on content / questions.

Positive	Things which could be improved
Very colourful and interesting	You could put different colours on because it is just
Nice colour	cyan
Front cover nice and colourful	Different colours like red, blue, yellow
Good pictures	More pictures
Not too much writing	Less questions
1st pages and last pages are best	Writing could have been bigger
Better than the other ones	The writing could be bigger
It is good	Mid pages are bit boring
Good	

Appendix 13 Extracts from CRAG discussion on questionnaire development

Notes on use of CRAG meeting 3 “best ever science centre” exercise to inform questionnaire development

Topic / content specific contents not incorporated into questionnaire because the themes identified with CRAG are “help learning”, “enjoy more”, “how it makes you feel about science”. For same reason omitted comments on physical environment / facilities, beyond one comment re look and feel of place.

Bubble machine - topic / content

Sensible equipment – unsure if this would fit with themes “help learn”, “help enjoy” or “feel about science”

Gift shop - physical environment

Friendly staff / helpful staff—already incorporated elsewhere based on CRAG meeting 4

Safe, safe and sensible activities - don’t know which theme this would fit

Stylish - the look of the place, and cleanliness / tidiness came up under the theme “help enjoy” so this is incorporated

Stuff for kids, science games—incorporated within “help learn” based on CRAG meeting 4

Make volcanoes—topic / content

Tidy toilets, have a café with nice food, slush puppy machine - physical environment

Nice staff—incorporated based on CRAG meeting 4

Experiments challenges, make your own—incorporated based on CRAG meeting 4

iPads to research on— incorporated based on CRAG meeting 4

Volcano—topic / content

Explosions / fire—topic / content

Cool challenges / treasure hunts—incorporated based on inclusion of “challenges” in CRAG meeting 4

A dome that is projected onto to make a life like science—topic / content

To make your own things like robots – unsure if this would fit with themes “help learn”, “help enjoy” - not incorporated

Static electricity—topic / content

Food experiments—topic / content

Presentations about science – included in “help learn” - incorporated based on CRAG meeting 4

Computers to research on—incorporated based on CRAG meeting 4

Lots of colour—incorporated based on CRAG meeting 4

Some games you can interact with—incorporated based on CRAG meeting 4

Lots of things to do—incorporated based on CRAG meeting 4

Cool to see machines used over the years—topic / content

Learn about the moon—topic / content

Interesting, to learn something you didn't know before—incorporated in “learn” theme

Biodiversity—topic / content

Learn to detect illnesses, cancer etc—topic / content

Lots of things to touch, smell, see, hear—incorporated in “learn” theme

There would be all the facts next to the inventions—incorporated in “learn” theme

It would have the best science things from all around the world-incorporated in “learn” theme

It would have lots of different rooms and all the rooms will be science from different countries—incorporated in “learn” theme

Lots of pictures of inventions on the walls—incorporated in “learn” theme

I would be amazed—incorporated based on CRAG meeting 4

Fascinating things for kids to do and learn science from—incorporated based on CRAG meeting 4

Lots of experiments happening towards the same thing—incorporated in “learn” theme

Notes from CRAG meeting 4 discussion:

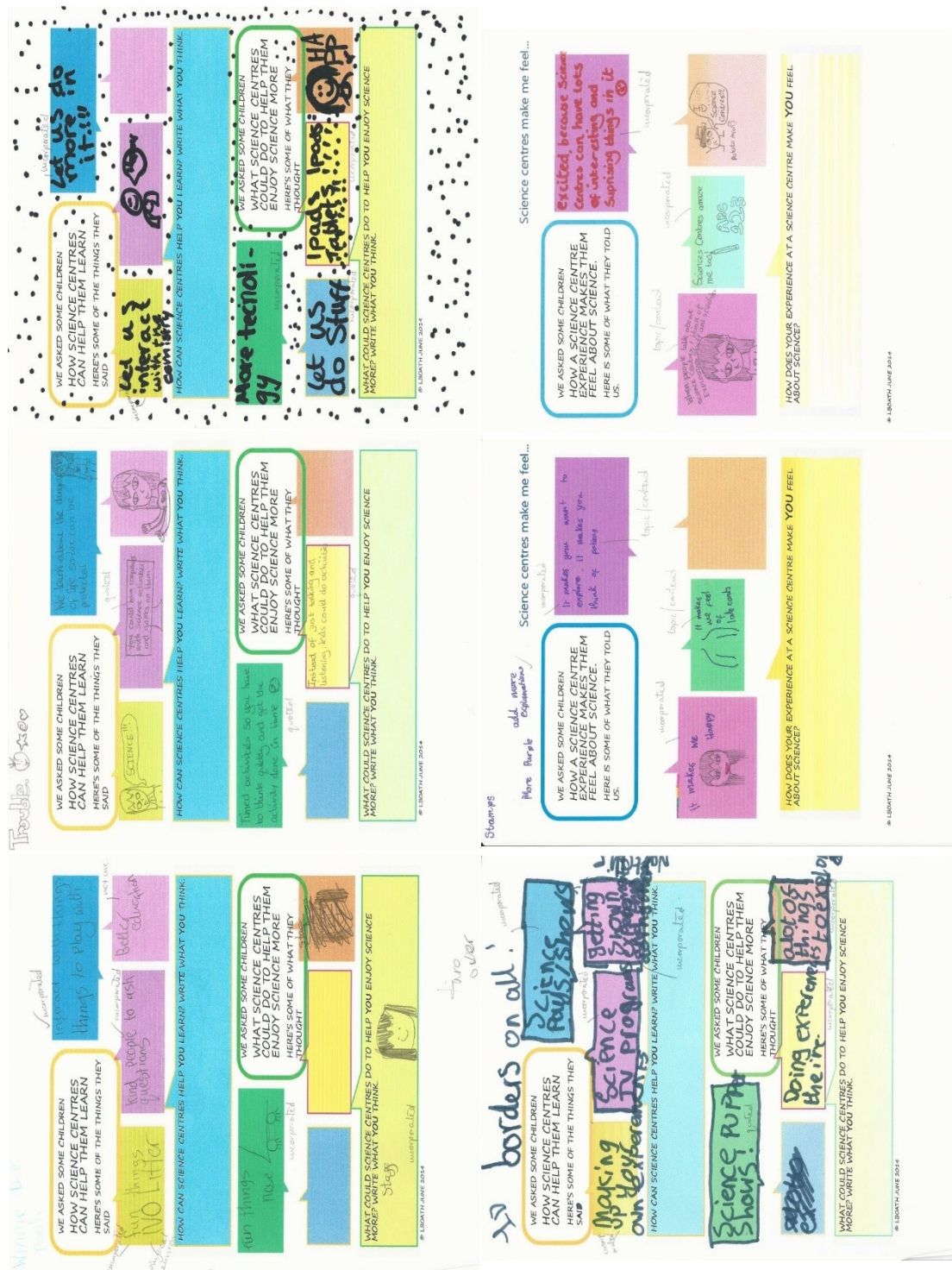
- page 1 (characteristics) discussion on whether it should have an additional option “I am at the science centre with my class”. Agreed that some children may be visiting with school group, not only or not necessarily class group, so having this change would be confusing. Request for more colour, and borders.
- page 2 (qu 1-3) addition to “which science things do you enjoy” to add “doing experiments”. Discussion about whether a separate line needed for “science centres” – agreed that comes under “visiting places to do with science”.
- page 3 (qu 4) adjust headings to make clearer. Discussion about whether the words “yes”, “not sure” and “no” should be replaced with happy faces. Unable to identify a system that CRAG thought would be clear, make sense and mean the same, so agreed to leave as is.
- page 4 (how you feel) requests for more colour and contrasting borders round the speech bubbles. Children happy with the square speech bubbles, this made sense to them. Populated these using the children's words from CRAG meeting 4 in response to this question, also reviewed last week's “best ever science centre”
- page 5 (help you learn) more colour, borders. Populated using the using the children's words from CRAG meeting 4 in response to this question.
- page 6 (help you enjoy) more colour, borders. Populated using the using the children's words from CRAG meeting 4 in response to this question. Also incorporated information from “best

science centre ever”, discussion noted in field notes and audio recorded, and from final page “anything else you’d like to tell us” which came under the “I would like to...”

Note: excluded anything specifically to do with requests for topics / content e.g. rockets, robots, space, biodiversity since this is about attitudes and experiences, as opposed to content children would like to have included.

- main themes of how the experience makes children feel about science, learning and enjoyment confirmed by CRAG: no other themes identified
- important that experiences at science centres more interactive – more doing not just watching
- staff should ensure that they are not just picking one or two people to do things – often same people who always get picked – doesn’t help others learn or gain confidence
- tidiness and the look very important to children
- wording on the final page, children felt this was problematic – they thought it would be taken to mean “things you would like to know about science or science centres”. Various suggestions proposed by CRAG participants and discussed. Suggestion agreed upon: “is there anything else you would like to tell us about science or science centres? Write or draw here!”

Appendix 14 CRAG responses to trial questionnaires (annotated)



Natolie **# Science**
Science centres make me feel...

WE ASKED SOME CHILDREN HOW A SCIENCE CENTRE EXPERIENCE MAKES THEM FEEL ABOUT SCIENCE. HERE IS SOME OF WHAT THEY TOLD US.

I think it is good to have a science centre because then you can learn more about science.

Put a background colour for the question

HOW DOES YOUR EXPERIENCE AT A SCIENCE CENTRE MAKE YOU FEEL ABOUT SCIENCE?

© LBoath 2018

different colour of border for the digren boxes

EXPERIENCE MAKES THEM FEEL ABOUT SCIENCE. HERE IS SOME OF WHAT THEY TOLD US.

Chazzy! because when I see a science I see cars coming in!

HOW DOES YOUR EXPERIENCE AT A SCIENCE CENTRE MAKE YOU FEEL ABOUT SCIENCE?

© LBoath 2018

Science centres make me feel...

WE ASKED SOME CHILDREN HOW A SCIENCE CENTRE EXPERIENCE MAKES THEM FEEL ABOUT SCIENCE. HERE IS SOME OF WHAT THEY TOLD US.

I think! has a perate amount of colour

HOW DOES YOUR EXPERIENCE AT A SCIENCE CENTRE MAKE YOU FEEL ABOUT SCIENCE?

© LBoath 2018

take the colours from the space bubbles and use them on boat days on different boxes.

Having Compling

HOW CAN SCIENCE CENTRES HELP YOU LEARN? WRITE WHAT YOU THINK.

Have Books about Science

WE ASKED SOME CHILDREN WHAT SCIENCE CENTRES COULD DO TO HELP THEM ENJOY SCIENCE MORE. HERE'S SOME OF WHAT THEY THOUGHT.

Learn how to do your own research

Drawn up to help you learn

WHAT COULD SCIENCE CENTRES DO TO HELP YOU ENJOY SCIENCE MORE? WRITE WHAT YOU THINK.

© LBoath 2018

WE ASKED SOME CHILDREN HOW SCIENCE CENTRES CAN HELP THEM LEARN. HERE'S SOME OF THE THINGS THEY SAID.

Let us have more time on the things in the science centre

US and explain things better

So we understand

HOW CAN SCIENCE CENTRES HELP YOU LEARN? WRITE WHAT YOU THINK.

Giving us some clues

Explain things better

Newer Technology

WE ASKED SOME CHILDREN WHAT SCIENCE CENTRES COULD DO TO HELP THEM ENJOY SCIENCE MORE. HERE'S SOME OF WHAT THEY THOUGHT.

WHAT COULD SCIENCE CENTRES DO TO HELP YOU ENJOY SCIENCE MORE? WRITE WHAT YOU THINK.

© LBoath 2018

WE ASKED SOME CHILDREN WHAT SCIENCE CENTRES COULD DO TO HELP THEM ENJOY SCIENCE MORE. HERE'S SOME OF WHAT THEY THOUGHT.

we could do more experiments

WHAT COULD SCIENCE CENTRES DO TO HELP YOU ENJOY SCIENCE MORE? WRITE WHAT YOU THINK.

© LBoath 2018

Appendix 15 E-mail correspondence with primary school re questionnaire pilot

Dear Head Teacher

date

I am currently doing my PhD at Trinity College Dublin, looking at children's experiences of, and attitudes to, experiences of science outside the "formal learning" environment. This is within a socio-cultural framework, with an explicit children's rights-based approach, in line with the United Nations on the Convention of the Rights of the Child.

I have been working with a Children's Research Advisory Group at a primary school, with ethical approval from Trinity and from Perth and Kinross Council. We are at the stage where we have a questionnaire developed with guidance from this group, and I'm keen to pilot it before the summer break. Whilst I couldn't use your primary school for data collection for the study, because of personal contact with pupils who attend the school, I wonder if you might be willing to allow children in P6a and P6b who are happy to do so, to complete the questionnaire about their experience of science outside school. I'm thinking that because they visited a science centre in November last year, they have an experience on which to base this, but the questionnaire is not designed around a specific experience, rather any experiences they have had, whether at somewhere like Deep Sea World, Our Dynamic Earth, a wildlife park etc. The questionnaire is about experiences whether with a school group or otherwise. It is particularly helpful for me to have children test it who haven't very recently been in a science centre or similar, because we tend to find that when children fill in such surveys close to the time of visit, there is always a positive response.

The completion would take 15-20 minutes. The questionnaires are anonymous, no child can be identified, and this pilot would inform the finalisation of the questionnaire for implementation in date. None of the data would be used as part of the study itself. I would provide hard copies of the questionnaire, whether you think it might be feasible to do with a small group of e.g. 5-10 children, or whether you would be happy to have the whole cohort involved.

I appreciate we are close to the end of term, and all will be very busy, so if it is not possible to accommodate this, I will fully understand.

Many thanks,
Lauren Boath

Mrs Boath

date

Happy to help! If you could give us a copy and we will print off for you here. I am sure both class teachers will be happy to oblige. They are at the High School tomorrow so Thursday or Friday would be possible!

Kind regards, Acting Headteacher, Primary School.

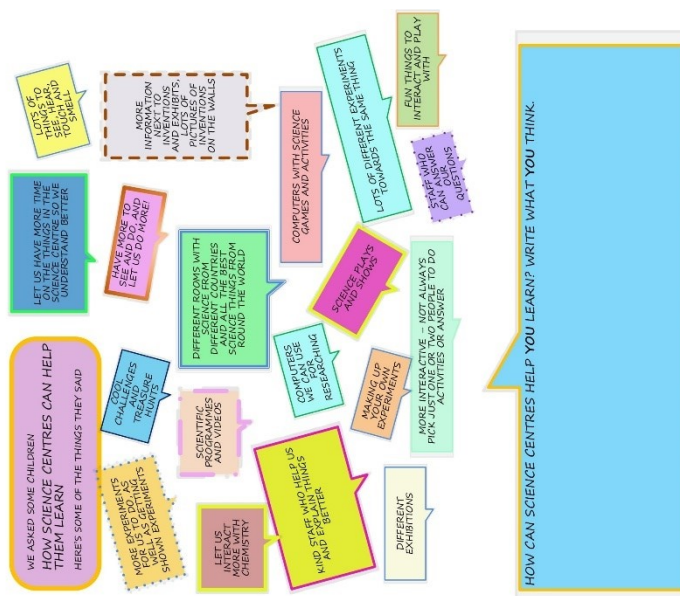
331

© LBoath 2018

© LBoath 2018

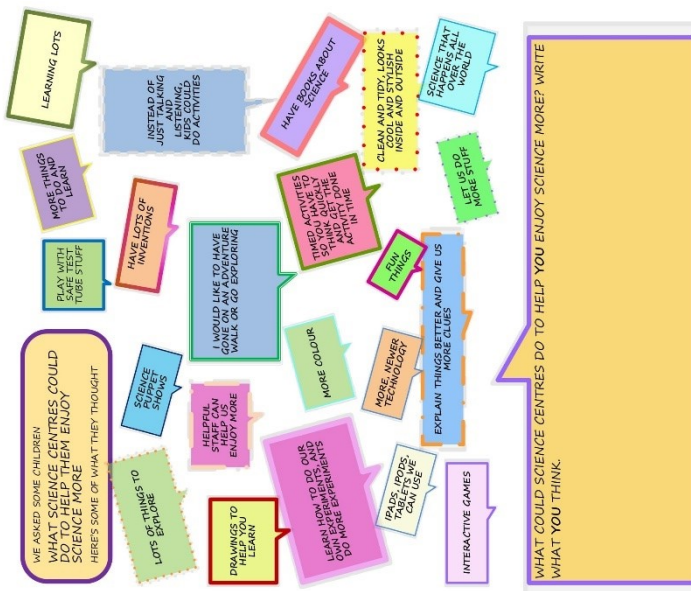
© LBoath 2018

I think science centres should...



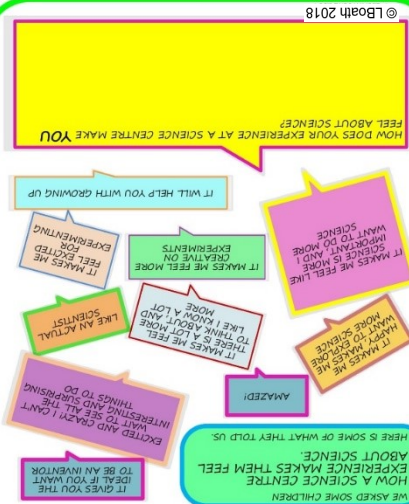
© LBoath 2018

I think science centres should...



© LBoath 2018

Science centres make me feel...



© LBoath 2018

Thank you for telling us what you think 😊

IS THERE ANYTHING ELSE YOU WOULD LIKE TO TELL US ABOUT SCIENCE OR SCIENCE CENTRES? WRITE OR DRAW!

Appendix 17 Schools (primary) contacted for questionnaire distribution

School	Local authority	Questionnaires		
		Requested	Returned completed	% completed
ANG01	Angus Council	24	24	100
FIF01	Fife Council			
FIF02 ³⁷		26	23	88
FIF03		Additional research committee approval required		
DUN01				
DUN02	Dundee City	30	22	73
DUN03 ³⁸	Council	35	33	94
DUN04	Perth and Kinross Council			
PKC01				
PKC02				
PKC03		Staffing changes		
PKC04		New HT, departure of science lead		
PKC05 ³⁹		52	48	92
PKC06		New HT, previous moved to another school		
PKC07		Small school with joint headship		
PKC08		HT long term absence, DHT acting		
PKC09		17	14	82
PKC10		26	26	100
PKC11				
PKC12		29	29	100
PKC13		57	51	89
PKC14		180	159	88

³⁷ Return slip indicated 2 children absent and return of 24 complete questionnaires. Only 23 included in envelope.

³⁸ Reported 2 children absent

³⁹ A further 28 questionnaires completed by class of 28 in this school, with three participating classes in total. Two of the three returned packets arrived; the missing packet could not be traced.

School	Local authority	Questionnaires		
		Requested	Returned completed	% completed
PKC15		Copy of PKC approval letter requested and provided; no further communication received		
PKC16		Research request did not align with priorities in school development plan		
PKC17		HT long term absence		
PKC19		110	103	94

Appendix 18 Communication with Head Teachers in respect of invitation to participate

Home address

Dear Headteacher

I am a GTCS registered teacher of physics with science who is currently undertaking doctoral research in science education at Trinity College Dublin. The subject of this research is 'Learner Voice: an exploration of the use of an explicit "United Nations Convention on the Rights of the Child" based approach to understand children and young people's experiences of, and attitudes to, learning science outside the school environment'. This research has been approved via the ethics procedures at Trinity College Dublin.

I would like to invite children in P7 to fill in a questionnaire about their experiences of science outwith normal lessons. They may base responses on experiences such as visits to a science centre or nature reserve for example, with the school or with family. It may also be visits to the school from e.g. the outreach team of Edinburgh International Science Festival. The experience or experiences may have taken place at any time in the child's life.

I have included a copy of the questionnaire for your information. There will be no information collected from which individuals could be identified. There is a short video (1.5 min) explaining the research to children, which you can access here:

<https://drive.google.com/file/d/0B816yG9ZahKYaUNINKVkSEE5cjg/view?usp=sharing>. I have also included a transcript of this video for your information.

I would be grateful if you could complete and return by Friday 14th November, the enclosed reply slip indicating whether or not you would be willing to pass on this invitation to participate to the children. I would provide the questionnaires in hard copy, the video to share with the children on a pen drive and a prepaid return envelope for the questionnaires.

Should you have any questions, please do not hesitate to contact me on *university email address* or *home telephone number*. I look forward to hearing from you.

Yours sincerely

Lauren Boath

GTCS *registration number*

Appendix 19 Schools (secondary) contacted for questionnaire distribution

School	Local authority	Questionnaires		
		Requested	Returned completed	% Return completed
ANG02	Angus Council			
ECC01	Edinburgh City	160	156	98
	Council	200	184	92
FIF04	Fife Council	193	171	89
FIF05				
PKC18	Perth and Kinross Council			

Appendix 20 Significant correlations (Spearman's rho)

Significant correlations between liking learning science in school and other responses from participants

Correlation between liking learning science in school and other responses	Spearman's rho	significance
Good at science?	0.428	***
My science experience was fun	0.372	***
My science experience was interesting	0.359	***
My science experience increased my curiosity about things	0.343	***
My science experience encouraged me to be creative	0.305	***
My science experience made it easy for me to learn	0.292	***
My science experience increased my understanding of the world around me	0.279	***
Enjoys a greater number of 'science things'	0.256	***
My science experience has shown me how science affects our way of living	0.253	***
My science experience made me think about jobs	0.251	***
My science experience helped me think about environmental, technological and scientific issues	0.243	***
My science experience involved exploring new things	0.239	***
Enjoys doing experiments with science kits	0.232	***
My science experience made me think	0.192	***
My science experience gave me a chance to use modern technologies	0.176	***
Enjoys visiting places to do with science	0.174	***
Enjoys reading science magazines	0.169	***
My science experience helped me to understand Scotland and its place in the world	0.167	***
Enjoys other 'science things'	0.118	***
Enjoys watching science TV programmes	0.117	***

Significant correlations between "My science experience made it easy for me to learn" and other responses

Correlation between "My science experience made it easy for me to learn" and other responses	Spearman's rho	significance
My science experience was fun	0.313	***
My science experience was interesting	0.313	***
My science experience has shown me how science affects our way of living	0.307	***
My science experience increased my understanding of the world around me	0.303	***
Like science?	0.292	***
My science experience increased my curiosity about things	0.282	***
My science experience helped me to think about environmental, technological and scientific issues	0.267	***
My science experience encouraged me to be creative	0.265	***
My science experience involved exploring new things	0.254	***
Good at science?	0.244	***
My science experience helped me to understand Scotland and its place in the world	0.235	***
My science experience made me think	0.188	***
My science experience gave me a chance to use modern technology	0.185	***
My science experience made me think about jobs	0.163	***
Enjoys a greater number of 'science things'	0.158	***
Enjoys visiting places to do with science	0.149	***
Enjoys reading science magazines	0.096	***
Enjoys doing experiments using science kits	0.103	***

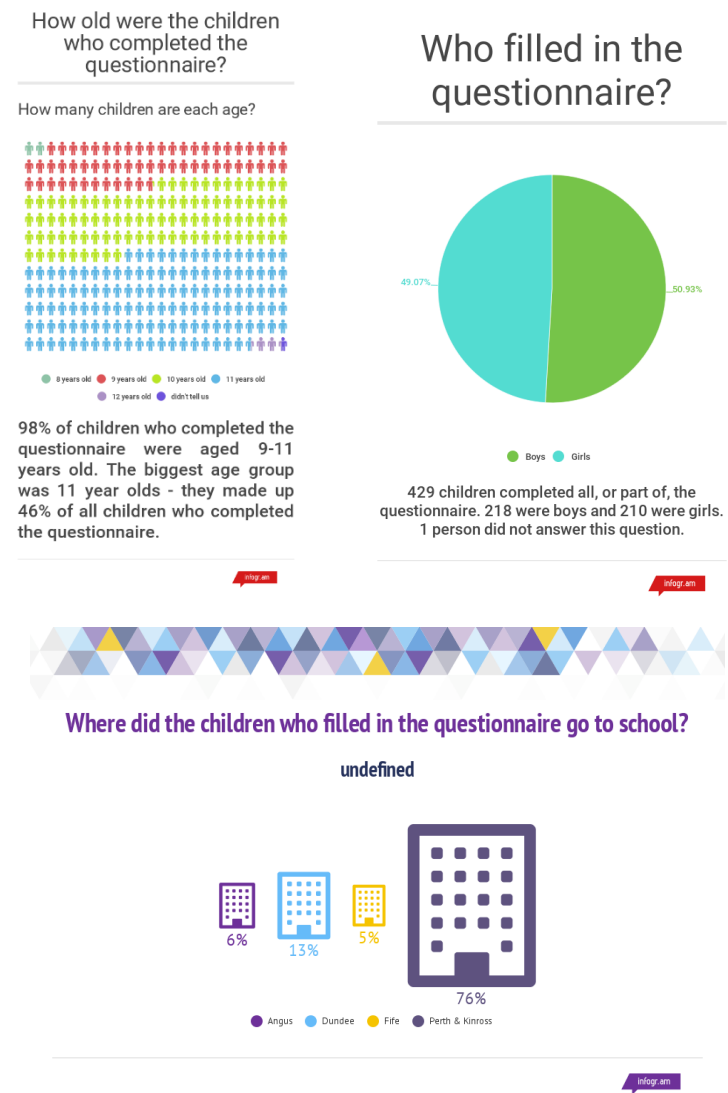
Significant correlations between "My science experience was fun" and other responses

Correlation between "My science experience was fun" and other responses	Spearman's rho	significance
My science experience was interesting	0.487	***
Like learning science in school?	0.372	***
My science experience increased my curiosity about things	0.327	***
My science experience made it easy for me to learn	0.313	***
My science experience encouraged me to be creative	0.312	***
My science experience involved exploring new things	0.300	***
My science experience has showing me how science affects our way of living	0.260	***
My science experience increased my understanding of the world around me	0.257	***
My science experience made me think	0.244	***
Enjoys a greater number of 'science things'	0.227	***
My science experience helped me think about environmental, technological and scientific issues	0.226	***
Enjoys visiting places to do with science	0.215	***
Good at science?	0.205	***
My science experience gave me a chance to use modern technologies	0.189	***
My science experience made me think about jobs	0.184	***
My science experience helped me to understanding Scotland and its place in the world	0.167	***
Enjoys doing experiments with science kits	0.149	***
Enjoys watching science TV programmes	0.100	***
Age of participant	-0.135	***

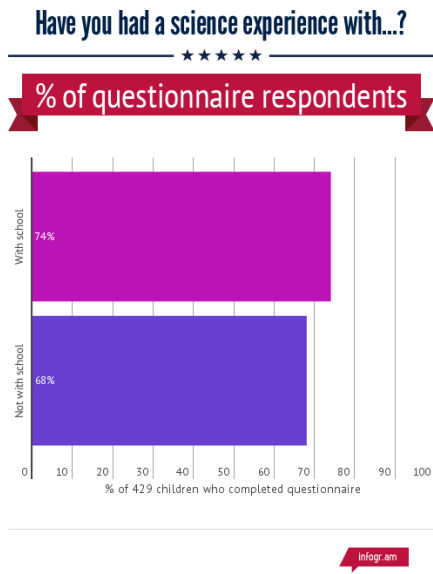
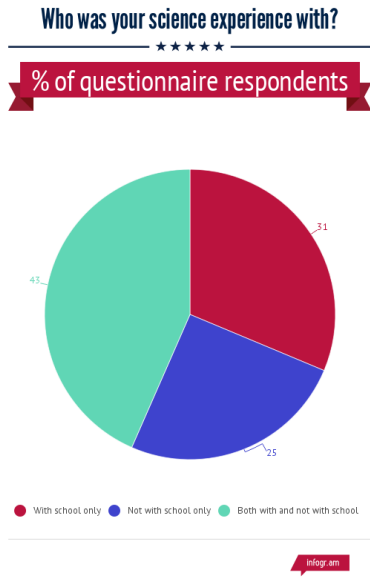
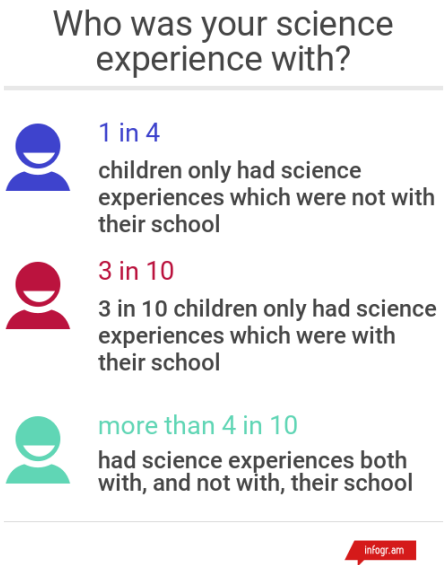
Significant correlations between "My science experience made me think about jobs" and other responses

Correlation between "My science experience made me think about jobs" and other responses	Spearman's rho	significance
My science experience encouraged me to be creative	0.366	***
My science experience increased my understanding of the world around me	0.265	***
My science experience helped me to understand Scotland and its place in the world	0.261	***
Like science?	0.251	***
My science experience helped me to think about environmental, technological and scientific issues	0.248	***
My science experience made me think	0.245	***
My science experience gave me a chance to use modern technology	0.238	***
My science experience has shown me how science affects our way of living	0.227	***
My science experience increased my curiosity about things	0.219	***
Good at science?	0.201	***
My science experience involved exploring new things	0.180	***
My science experience made it easy for me to learn	0.163	***
My science experience was fun	0.184	***
Enjoys a greater number of 'science things'	0.177	***
My science experience was interesting	0.138	***
Enjoys reading science magazines	0.128	***
Enjoys doing experiments with science kits	0.126	***
Enjoys nature walks	0.111	***

Appendix 21 Examples of demographic data visualisation for CRAG



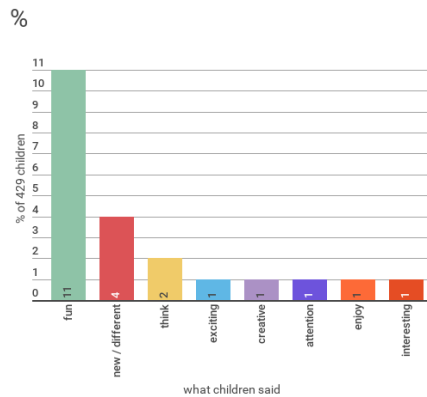
Appendix 22 Data visualisations of responses to question "who was your science experience with?"



Appendix 23 Visualisations of participant responses to question "How can science experiences help you learn?"



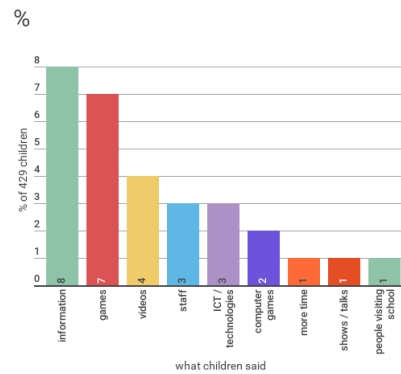
For science experiences to help me learn they should...



-  **fun**
be fun
-  **new / different**
show me things that are different, give me the opportunity to learn new things
-  **think**
make me think
-  **exciting**
be exciting
-  **creative**
encourage creativity
-  **attention**
catch my attention
-  **enjoy**
be enjoyable
-  **interesting**
be interesting

info:gr.am

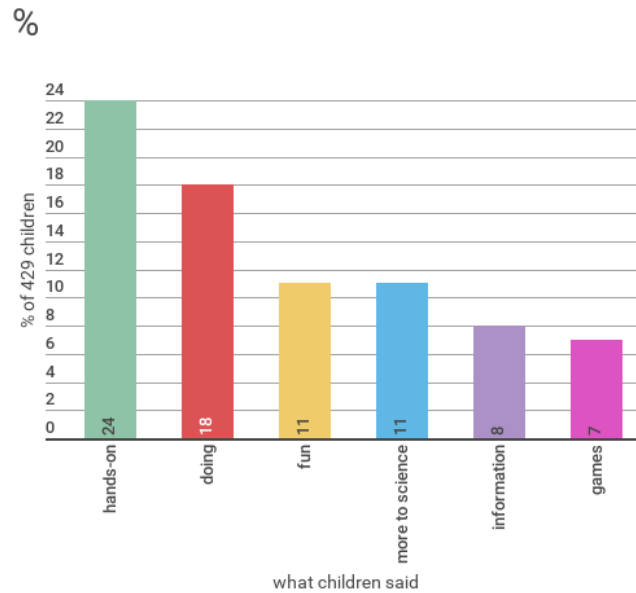
For science experiences to help me learn there should be...



-  **information**
more information, more detail, more challenge or the opportunity to do my own research
-  **games**
games, puzzles, quizzes or challenges
-  **videos**
programmes or videos about science for me to watch
-  **staff**
staff who are knowledgeable, who are able to listen and explain, who listen to my questions
-  **ICT / technologies**
ICT and technologies
-  **computer games**
computer games to do with science
-  **more time**
more time to learn, not so rushed
-  **shows / talks**
shows, talks and plays
-  **people visiting school**
people visiting the school

info:gr.am

How can science experiences help you learn?



hands-on

by being hands-on or interactive, with experiments, activities, inventions or equipment



doing

by letting me do and try things, not just watching and listening. By letting me play with things, by letting me do my own experiments and try my own ideas.



fun

by being fun



more to science

by showing that there is more to science than experiments, by showing different forms or applications of science, or by showing the impact of science and why it matters



information

provide more information, more detail, more challenge or the opportunity to do my own research



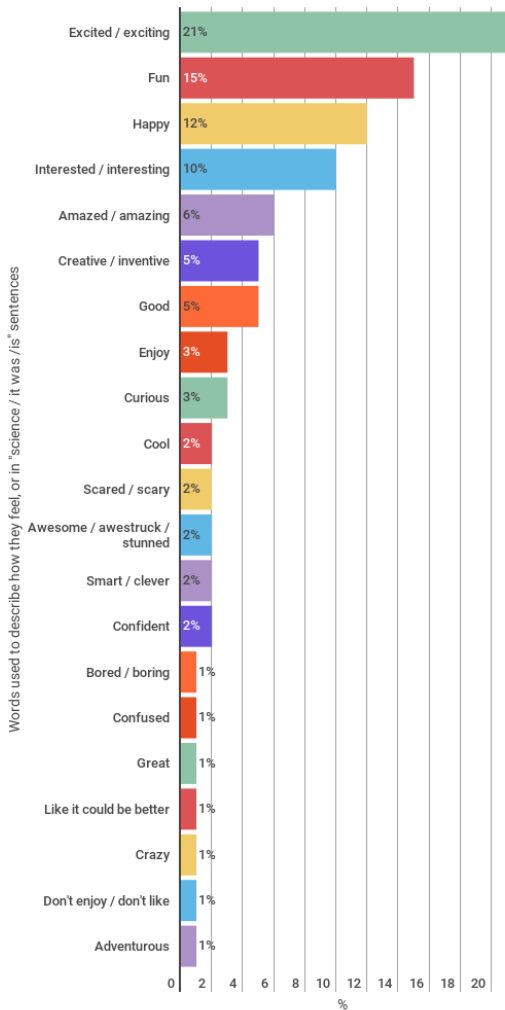
games

games, puzzles, quizzes or challenges

Appendix 24 Visualisations of participant responses to question “How do science experiences make you feel about science?”

How do science experiences make children feel about science?

% of children who said "it makes me feel...", "it is..." or "it was..."



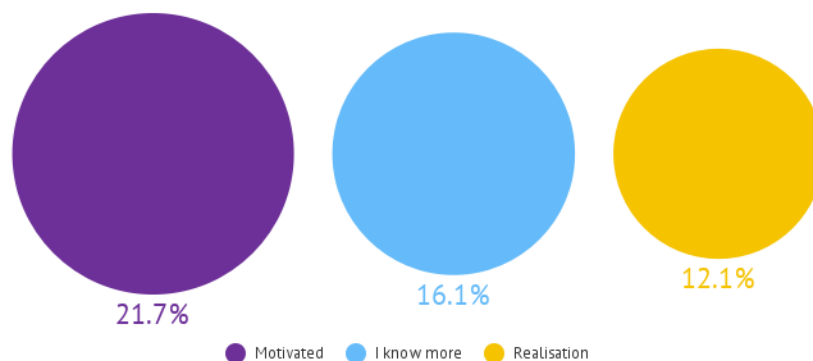
To make this graph, I counted up how many times each word was used in answer to the question "how do science experiences make you feel about science?".

For example, 91 children used the word "excited" or "exciting" in their answer. That is 21% of the 429 children who completed all or part of the questionnaire.

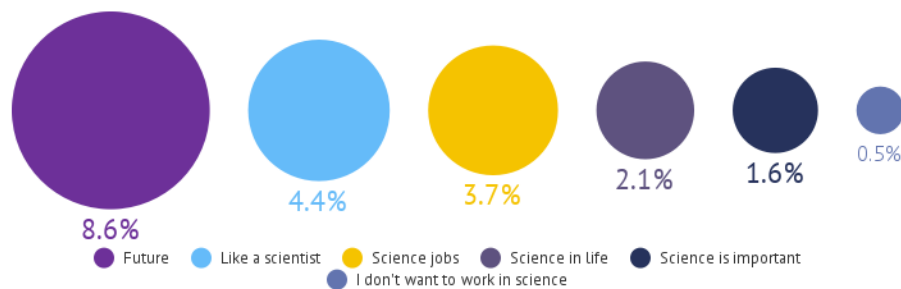


We asked children "How do your science experiences make you feel about science?"

These are the kinds of things they said.



The "motivated" bubble includes responses in which children talked about being motivated to do, know or learn more.
The "I know more" bubble includes responses in which children talked about knowing more or having learned.
The "realisation" bubble includes responses in which children talked about the realisation there is more to know, more out there, or the wider impact of science.



"Future" - responses in which children talked about the future, or about growing up

"Like a scientist" - responses in which children talked about feeling like a scientist, including 'real' or 'proper' scientists

"Science jobs" - responses in which children talked about wanting to be a scientist or work in a job involving science

"Science in life" - responses in which children talked about the role of science in life

"Science is important" - responses in which children talked about science as 'important'

"I don't want to work in science" - responses in which children said it made them feel they don't want to work in science

Appendix 25 Extracts of transcript of CRAG meeting 8

CRAG participants' discussion about question 5 "How do your science experiences make you feel about science?" using data visualisations based on word counts

This sub-group included five participants. Where I could identify participants by voice from the audio recording, this is noted in the transcript; otherwise these are denoted XY for unknown gender and XG for unknown girl.

CRAG (CG): So how does science experiences make children feel about science?

[inaudible]...exciting...so 21% said excited...fun was 15%...guys no seriously we have to...so let's...so 21% of them said they were excited. Yep.

CRAG (JB): Exciting...

CRAG (CG): But does that surprise you?

CRAG (JB): You can make things and stuff. Like make buildings. Like what we done last year.

CRAG (FG): I'm quite surprised that they did kind of, that interesting is only 10% and not higher

CRAG (DG): Adventurous 1% - what could adventurous mean?

CRAG (FG): Kind of like creative...look adventurous

CRAG (CG): I'm not really surprised that...wait... 1% of them said it was boring

CRAG (FG): What one are you the most surprised at?

CRAG (XY): Or you're not surprised?

CRAG (DG): Enjoy, enjoy's only 3%

CRAG (JB): Cool, cool's only 2%

CRAG (FG): Scared, scary...

CRAG (LB): Do you think more people would have said it's cool?

CRAG (JB): Yeah, cos like 'cool'

CRAG (FG): What is this meant to mean? 'Scared / scary'?

Researcher: So [inaudible]... it was scary

CRAG (NG): You know how, like, loud bangs and stuff when it comes to science, that's what they mean

CRAG (NG): Oh yeah, I was just like 'wait, how can it be scary?'

...

CRAG (CG): Yeah, 'fun', 'enjoyment' and 'good' should all be one

...

CRAG (JB): What does 'motivated' mean FG? What does motivated mean?

CRAG (FG): Motivated means kind of you're encouraged.

...

CRAG (CG): 4.4% said 'like a scientist'

[inaudible]

CRAG (CG): And then half of them said...0.5% said 'I don't want to work in science'...so does any of them surprise you?

...

CRAG (CG): So, did anything else surprise you? 'I know more' should have been more...

CRAG (CG) asks researcher: What does 'realisation' mean?

Researcher: So, this one is where children talked about 'more to know, more out there, or the wider impact of science'. And you can see the ones down the bottom for example...

CRAG (CG): I would have thought they would know more...than just 16 of them.

CRAG (LB): That's 16%, so that's less than 1 in every 5 that answered said 'I now know more' or 'I have learned something'...is that lower than you expected then?

CRAG (CG): Yes, because you'd have thought if they'd done an experiment or something, they would have learned more. Or going out on a nature walk, learned more than they already did.

Researcher: So, what might be behind that, do you think? For example, if they already knew everything?

CRAG (CG): Yeah maybe

Researcher: Or what other things might that mean?

CRAG (CG): Maybe if they only learned one new thing

Researcher: Is that the only possibilities for that answer?

CRAG (XG): Umm, yeah.

Researcher: I have put these ones in, these are very low numbers, just so you can see the range, because it did go down to some people, said 'I just don't want to work in science', 'I don't like science'

CRAG (XG): That's okay because that's their own opinion, maybe it's not just their strongest or their favourite subject

CRAG participants' discussion about question 5 "How do your science experiences make you feel about science?" using full responses written by research participants

Seven members of the CRAG participated in the discussion to which this transcript refers. The boys participating are identified as JB, KB and MB. XB denotes an unknown boy, where it was not possible to identify from the audio recording. The girls participating are identified as AG, CG, DG and FG. YG denotes an unknown girl, where it was not possible to identify from the audio recording. XY indicates unknown boy or girl.

CRAG (XY): Can we read these out and see what we think

Researcher: Go for it, oh yeah if you'd like to...

CRAG (AG): 'Science makes me want to explore the world and others around me, and want to do more science experiments'

Researcher: Okay, so what would you say, if you had to sort these into piles, you're thinking 'where would they go?' Should we hear a few different ones, from different people before we...

CRAG (CG): I'll go next. 'I feel better about science and confident when I go to high school'

CRAG (FG): 'I feel amazed about all the sciencey things, it also makes you think more clearly and I loved learning more, hope to learn more in the future'

CRAG (DG): 'I am happy to be part of science, it is so amazing, and I can't wait to see what the future holds'

CRAG (JB): 'Fun and a bit scary and impressed. Science helps you know the outside world and it also gives you ideas and makes you feel like you want to be a scientist'

CRAG (MB): 'It makes me want to get more into it, and I just love doing science'

CRAG (KB): 'Science experiments make me feel like a scientist and make me think more about the world'

Various: I've got more, I've got another one.

Researcher: If you're happy to read, let's just zip through them all then.

Group read out the statements, one after another. CRAG participants query a sentence which doesn't make sense, I note that I have written exactly what was said even where a word has been missed or the meaning is unclear.

Researcher: Okay, so...as you're listening to those, is there anything that jumps out, what do you think is a main thing that people are saying, or anything that you have noticed that people are saying...?

CRAG (AG): About that they want to do more.

Researcher: So, want to do more of it? So, what I thought we'd do is, if you have got one that you think is about wanting to do more, and some of these are about lots of different things, just on the back of it, erm, if you could just scribble down, 'do more'. If we think that's a theme and we think we've got one that's about that...

CRAG (RG): I've got two...

CRAG (YG): I've none.

Researcher: That's fine. If you're looking and saying 'no, none of mine are about that' then...

CRAG (DG): Wait, could it be like more than one thing on it?

Researcher: Absolutely, yes...

CRAG (DG): Because some of them are like...

Researcher: ...so complicated, that one you read was like an essay, wasn't it?

CRAG (DG): I know.

CRAG (CG): Would it be 'science encourages me...', that would be 'do more'? 'To understand more...'

Researcher: To understand more about...so what do we think?

CRAG (AG): If there's a word 'more' write 'do more'

Researcher: Okay, so you think if the word features...what do you think, is that what that person is saying 'science encourages me to try to understand more about the world?'

CRAG (XY): No

CRAG (KB): Mine says 'makes me think more about the world around me'

Researcher: So, are you putting that under 'do more'?

CRAG (KB): No.

CRAG (AG): Mine is like what the future holds and doing things when I'm older and stuff.

Researcher: Okay. So that would come...

CRAG (KB): Cos it makes them think. [5 minutes 14 seconds]

Researcher: So, this process...there's no right answer, this is exactly what researchers do is, and this is what I've tried to do home, is sit there saying 'now is that what I think...'. You know you're saying they have said 'think more, well I don't think that's the same thing' and that's basically what I'm doing is making all these judgements, and that's what's so valuable is that you are making judgements from the perspective of people like you, whereas I am making them as an adult. Okay, any other theme then that we think jumps out, any other...something we've noticed?

CRAG (CG): Erm, confident

Researcher: Okay, about confidence. Does anyone think they've got any others that talk about confidence?

Various: Me. Mine doesn't.

Researcher: And it doesn't mean there aren't elsewhere in the (responses), because remember this is just a few of 429...so we didn't find any others with confidence? But do you want to write that on the back of that one, so that I remember?

CRAG (CG): Yeah!

CRAG (AG): Kind of like doing it in the future and stuff.

Researcher: Okay, so themes about...people's futures?

CRAG (XY): Yeah something about the future...

CRAG (KB): Is this confident? It says they make me feel free and myself. They make me feel like I am able to do anything I want.

Researcher: Oh, do we think that would come under a theme of confident? Why don't you write that one down?

CRAG (AG): Are you allowed to write a few, a few themes on the back cos...

Researcher: Yes absolutely...that's what's so complicated about it is that I've given people free answers, so they might have said something that comes under futures, and confidence, and how much they like science and...

...

Researcher: So, does anyone else have one they think comes under futures, things in the future?

CRAG (CG): Yeah, I feel confident when I go to high school.

Researcher: So, as well as being about confidence, they're maybe talking about their future there, do you think?

...

Researcher: So, where did we go, did we get futures down? Anything else that's jumping out at you?

CRAG (AG): Something about, like, excited, like, excited to do more

CRAG (CG): Yeah, I've got that

Researcher: Excitement?

CRAG (FG): Happy?

CRAG (AG): They make feel excited, it makes me feel happy and excited, so something about feeling excited.

CRAG (MB): Yeah, I've got that too, excited.

CRAG (DG): And exciting, RG, remember exciting.

CRAG (FG): What would it be for this one?

Researcher: Hang on, we'll come to that in a second. So, what would we call that?

CRAG (DG): Excited.

CRAG (AG): Being excited?

CRAG (CG): Resilience?

Researcher: Okay, so if we put down excited but include in that, you say the ones about feeling happy about it? Yeah, okay.

CRAG (FG): Feeling smarter?

Researcher: ... Feeling smarter, anything else around that?

CRAG (CG): Brainier, brainy.

CRAG (KB): I've got one that says...

CRAG (JB): It tells you how to help the world or maybe take it as a job.

CRAG (KB): Mine says...science makes me feel like...

Researcher: So, might that be a 'futures' one?

CRAG (JB): Yeah

Researcher: Do you think that's also about...you know they feel smarter, so they could perhaps do it, is that what you're kind of...?

CRAG (JB): Yes

Researcher: Okay, so put that...

CRAG (KB): I have science experiments make me feel like a scientist. So...

CRAG (CG): That's kind of future because they want to be a scientist.

CRAG (KB): Well it doesn't say they want to be.

CRAG (AG): It doesn't say he wants to be.

Researcher: Yeah, that's what we have to be so careful of because sometimes...

CRAG (CG): But he said it makes me feel like...

Researcher: His underlying thing might be "it makes me feel like a scientist" and he might be thinking in his head "thank goodness I'm not one"...

CRAG (AG): Or her head.

Researcher: Yes, or her head, I'm just thinking him because KB read it, it absolutely might be a girl

CRAG (KB): It could be like, erm...

CRAG (CG): Or it could be both.

CRAG (FG): How could it be both?

CRAG (JB): DG what was yours?

CRAG (DG): What one? This?

CRAG (JB): Yeah, the one about...the smarter one. It was like...

Researcher: The big long one?

CRAG (JB): So, couldn't that be, "makes me feel smarter" as well? So, couldn't that be?

CRAG (DG): Yeah because it makes you feel like a scientist.

CRAG (DG): Like Albert Einstein and Stephen.

Researcher: So, you're saying for people to say they feel like a scientist, they're really saying they feel smarter?

CRAG (CG): Yeah...

CRAG (DG): Yeah

CRAG (JB): Yeah

CRAG (DG): Cos scientists are quite smart.

Researcher: Interesting, okay.

CRAG (JB): Well normally.

CRAG (CG): And life revolves around science.

CRAG (FG): But if, scientists have to be quite, like, smart because...

CRAG (CG): Life revolves around science

CRAG (OG): But, because if it's like, what do you call it, if you didn't do well with like maths and like science and all that in school, then it would be harder for you to be a scientist when you're older, if that's what you want to be, because you need to have all like the skills and stuff.

CRAG (RG): If you don't then you can't do the job.

Researcher: What do we think, any other themes coming through?

CRAG (AG): About exploring stuff? I think it will help me grow up...

CRAG (JB): That's your future

Researcher: Do you think that's a 'futures' one?

CRAG (CG): Yes, because growing up is part of your future. You get taller and stuff. Kind of develop, like does that make sense?

Researcher: Any other ones in your statements that you think could be under another theme that we've not mentioned?

CRAG (MB): I feel that science is exciting and amusing

Researcher: Okay so what...

CRAG (AG): Feelings

Researcher: Feelings about science? Positive feelings about science, or...? Or...I don't know, what does anyone else think? Does anyone else have anything a bit like that, that we might say...?

CRAG (KB): Fun and a bit scary and impressed.

Researcher: Okay. Anything else on that?

CRAG (AG): Something about exploring stuff...

CRAG (YG): I like exploring the world

CRAG (JB): Mine says "they make me think hard and think do I enjoy this, makes me feel...[inaudible]

CRAG (YG): Stuff about the world as well, there's like...

Researcher: Okay so does anyone have ones about the world...or?

CRAG (YG): Well erm, kind of

CRAG (JB): Erm, it's fun and it tells you how to help the world or maybe get a job.

CRAG (YG): Yeah like that.

CRAG (YG): I kind of have that, it says 'science we need it to survive'.

Appendix 26 Data relating to responses to questionnaire question “do you like learning science in school?”

Percentage of participants’ selecting positive response to question, using two-sample t-test between percents

Primary (n = 482)	Secondary (n = 462)	p-value	significance
92%	91%	➤ 0.50	not significant

Male (n = 531)	Female (n = 488)	p-value	significance
93%	91%	➤ 0.05	not significant

Strength of positive response to item through comparison of means

Primary (n = 482)	Secondary (n = 462)	significance
3.25	3.20	t(1028) = 0.0965 p = 0.035 *

Male (n = 531)	Female (n = 488)	significance
3.28	3.18	t(1028) = 0.0965 p = 0.034 *

Male age 13 (n = 135)	Female age 13 (n = 105)	significance
3.32	3.08	t(238) = 2.440, p = 0.015 *

Groups being compared	with	Significance
Males in primary school	Females in primary school	not significant
Males in secondary school	Females in secondary school	not significant
Males age 9	Females age 9	not significant
Males age 10	Females age 10	not significant
Males age 11	Females age 11	not significant
Males age 12	Females age 12	not significant

Appendix 27 Responses to question 4 “my science experience...”

