DEPOSIT AND CONSULTATION OF DISSERTATION

One copy of your dissertation will be deposited in ORA (Oxford University Research Archive), where it is intended to be freely available online. In order to facilitate this, you are requested to complete and sign the form below.

Please use block capitals

Surname

MILARSKI

First names (in full)

MEGAN REBEKAH

Faculty board EDUCATION

Degree name and pathway

MSC EDUCATION (RESEARCH DESIGN AND METHODOLOGY)

Title of dissertation

EXPLORING SCIENCE CAPITAL WITH PRIMARY-SCHOOL-AGED CHILDREN

N.B. The title stated here must be precisely the same as that stated on the title page of the thesis submitted. **A candidate wishing to amend the title previously approved by the faculty must apply to the faculty board for permission to do so.**

Supervisor

DR ALISON CULLINANE

Subject keywords *Enter your own keywords or phrases to describe your work. This information helps us describe your work in ORA*

SCIENCE CAPITAL
INFORMAL SCIENCE LEARNING
EQUITABLE STEM PARTICIPATION
RESEARCH WITH CHILDREN
CONSTRUCTIVISM
CRITICAL THEORY

Research methods used *This information helps us describe your work on SOLO for future students e.g. quantitative, interviews, vocabulary test, systematic review, etc.*

CASE STUDY
DIARY METHODS
QUESTIONNAIRES
ONLINE SEMI-STRUCTURED INTERVIEWS
THEMATIC ANALYSIS

Declaration by the candidate as author of the dissertation

1. I understand that I am the owner of this dissertation and that the copyright rests with me unless I specifically transfer it to another person.
2. I understand that the Department requires that I shall deposit one copy of my dissertation in the Oxford University Research Archive ('ORA') where it shall be freely available online for use in accordance with ORA's Terms and Conditions of Use [https://ora.ox.ac.uk/terms_of_use].
3. I understand that this dissertation should not contain material that can be used to personally identify individuals or specific groups of individuals, and that such material should be removed before this dissertation is deposited in ORA.
4. I agree to be bound by the terms of the ORA Grant of Non-exclusive Licence [www.bodleian.ox.ac.uk/ora/deposit-in-ora/deposit-licence] and I warrant that to the best of my knowledge, making my thesis available on the internet will not infringe copyright or any other rights of any other person or party, nor contain defamatory material.
5. I agree that my dissertation shall be available for download in ORA in accordance with paragraphs 2, 3 and 4 above.

Signed [an electronic signature is sufficient]: M. MILARSKI
Date: 6/10/2021



Exploring science capital with primary-school-aged children

Megan Milarski

Green Templeton College

Supervisor: Dr Alison Cullinane

Department of Education

Dissertation submitted in part-fulfilment of the requirements for the degree of

Master of Science in Education (Research Design and Methodology)

August 2021

ABSTRACT

It is widely recognised that there is an urgent need to make access to and engagement in science, technology, engineering, and maths (STEM) education more equitable, from both a social justice and economic perspective. The concept of science capital has been used as a tool to understand patterns in young people's perceptions of science, science identity and aspirations, with those categorised as having high science capital being more likely to feel that science is something they identify with and to continue with science post-compulsory education. Science capital encompasses all of the resources available to an individual that could be advantageous in the context of science, for example, knowing people who have science-related jobs, or consuming science-related media. Research has shown that science capital is patterned by structural inequalities, such as class, gender, and ethnicity. To date, the majority of the available research related to science capital has been conducted with children and young people aged 10–19 years old and in the context of formal science education. This study explored the concept of science capital in everyday settings through a multiple case study with four children aged 8–10 years old. Diaries, interviews, and questionnaires provided an insight into who and what children considered to be science-related in their lives. Thematic analysis of their responses demonstrated that there is a mismatch between the breadth of what children considered to be science-related and what is important for being science person, and what is traditionally valued and represented in the field of science. This apparent disconnect with everyday science by the field was reflected by a surprising absence of school science in children's diaries and interviews. The findings also added to a recognised challenge for equitable STEM education initiatives: none of the children agreed that people like them work in science despite agreeing that anyone can become a scientist. In light of this insight to science in the lives of a group of primary-school-aged children, reflections and recommendations are offered for the field of STEM education, including support for a science capital teaching approach that broadens what counts as science, and a call for time and training to equip young people, families, educators, and policymakers to actively challenge traditional and dominant science representations and practices.

ACKNOWLEDGEMENTS

Thank you so much to the children and families that participated in this research, it was a privilege and a pleasure to work with and learn from you. A huge thank you to Alison, I am incredibly grateful to have had you as my supervisor. Your patience, advice, respect, and encouragement while helping me to work through my (many!) thoughts, and generally being lovely to chat to made this dissertation possible and a brilliant learning experience. Thank you Ariel, Ashmita, Miranda, the two RDM cohorts I was lucky to be part of, and everyone who offered their time for the RDM course for the brilliant teaching, discussions, and guidance. Thank you to Jeremy and Abingdon School for facilitating my studies alongside working part-time, it has been a truly enriching experience. Finally, to Sam, for the endless support, patience, belief, and hugs. To my family, for being such a huge part of my drive and ambition for this work. I know I can always rely on you and I can never thank any of you enough.

TABLE OF CONTENTS

ABSTRACT ..... **i**

ACKNOWLEDGEMENTS ..... **ii**

TABLE OF CONTENTS ..... **iii**

LIST OF TABLES AND FIGURES ..... **vi**

CHAPTER ONE: INTRODUCTION **1**

1.1 Participation in STEM in the UK 1

1.2 Introducing science capital 2

1.3 Experiences and beliefs informing the study 3

1.4 Impact of COVID-19 4

1.5 Research aim and questions 4

1.6 Dissertation outline 5

CHAPTER TWO: LITERATURE REVIEW **6**

2.1 Conceptual framework 6

2.2 Key science capital research 10

2.3 Limitations of the science capital concept and research 12

2.4 Who and what is valued and represented in the field of science? 14

2.5 Summary 17

CHAPTER THREE: RESEARCH DESIGN AND METHODOLOGY **18**

3.1 Research design 18

3.1.1 Philosophical approach *18*

3.1.2 Research with children *19*

3.1.3 Study outline *20*

3.2 Participants 21

3.3 Data collection 21

3.3.1 Questionnaire *22*

3.3.2 Diary *23*

3.3.3 Interview *24*

3.4 Analysis 25
3.4.1 Questionnaire 26
3.4.2 Diary, interview and interview alternative 26
3.5 Ethical considerations 27
3.6 Summary 28
CHAPTER FOUR: FINDINGS 29
4.1 Research question 1: What events do children report as being science-related in their everyday lives? 29
4.1.1 Narrow definition (field-led) 29
4.1.2 Broad definition (child-led) 30
4.2 Research question 2: How do children explain why they see an event as science-related? 31
4.2.1 How things work 31
4.2.2 Components of science 31
4.2.3 Learning 32
4.2.4 Invention 32
4.2.5 Being 32
4.3 Research question 3: How do children explain why they see themselves or others as a science person? 32
4.3.1 Engage in science-related interests 33
4.3.2 Talk with people who are interested in science 34
4.3.3 Find things out 34
4.3.4 Have a science-related job 34
4.4 Thematic network 35
4.5 Research question 4: How do children's responses vary by children's science capital index score, gender, ethnicity, and indicators of socioeconomic status? 35
4.5.1 Case summaries 37
4.5.2 Cross-case comparisons 41
4.6 Summary 42
CHAPTER FIVE: DISCUSSION 43
5.1 Discussion of main findings 43
5.1.1 Children have a broad view of what and who is science-related in their everyday lives 43
5.1.2 School science 45
5.1.3 Anyone can become a scientist but people like me do not work in science 46

5.2 Evaluation of the research approach 46

5.3 Implications 48

5.4 Conclusion 49

REFERENCES 50

APPENDICES 64

Appendix A: Initial recruitment email 64

Appendix B: Information video for children - transcript 65

Appendix C: Information sheet for parents/guardians 66

Appendix D: Questionnaire 69

Appendix E: Interview schedule 75

Appendix F: Example visual prompts for online interview 77

Appendix G: Example offline interview activity sheet 79

Appendix H: Science capital index items and scoring 81

Appendix I: Initial codebook 83

Appendix J: Final codebook 85

Appendix K: CUREC and amendment approval 88

Appendix L: Consent form 89

LIST OF TABLES AND FIGURES

Tables

Table 1 Demographic information, science capital index quantile, and sources of data collected for each participant 22

Table 2 Events that children reported as science-related in the diaries and interviews 30

Figures

Figure 1 Global thematic network showing the themes identified from diaries and interviews about what events and who children see as science-related, and why 35

Figure 2 Children's responses to questionnaire items exploring science identity, science aspirations, and groups of science people in their lives 36

Figure 3 Individual thematic maps for each participant 37

CHAPTER ONE: INTRODUCTION

This chapter first highlights benefits and challenges of increasing and widening participation in science, technology, engineering, and maths (STEM). It then goes on to introduce science capital, a concept that has gained considerable attention in the STEM education field for its contribution to understanding young people's science identity and aspirations. My experiences of STEM education and the impact of COVID-19 are then discussed to illuminate the approach taken in this research to explore science capital with primary-school-aged children in the context of their everyday lives.

1.1 Participation in STEM in the UK

The importance of STEM has repeatedly been promoted by the UK government for reasons of increasing productivity and economic growth, and developing a technologically literate population (National Audit Office, 2018; Skilling, 2020; The Committee of Public Accounts, 2018). Consequently, there is ongoing concern about identified STEM skills mismatches in the workforce and in uptake of apprenticeships and undergraduate courses (National Audit Office, 2018). In addition, evidence shows that certain minoritised[1] groups in the population are underrepresented in the post-compulsory education STEM skills pipeline according to gender, ethnicity, and socioeconomic background (National Audit Office, 2018), and more research is needed to better understand the inequities faced by other groups, for example, according to disability, gender identity, and/or sexual orientation (APPG on Diversity and Inclusion in STEM, 2020). These patterns are also found to be reflected by children and young people at all stages of STEM education (APPG on Diversity and Inclusion in STEM, 2020; Archer et al., 2020).

While the economic imperative is often foregrounded, there is also a clear social justice imperative for increased and more equitable[2] participation in STEM (Moote et al., 2021). Not only are equity and diversity in STEM important for the workforce, an equitable distribution of STEM literacy among the population as a whole is also advantageous. It promotes individual agency, wellbeing, and a society that is equipped to engage with scientific information, and can offer opportunities due to the value placed on STEM skills and knowledge (APPG on Diversity and Inclusion in STEM, 2020; Kahn, 2015; Moote et al., 2021). As the government recognises, focusing on

[1] I echo Godec et al. (2021, p. 21) by using the term "minoritised (rather than minority) to indicate that an individual's minoritised status is a function of how they are positioned within society, rather than an inherent characteristic".

[2] Equity, rather than equality, is used deliberately throughout this dissertation to recognise that individuals have different expertise, needs and backgrounds that may require different support in order to provide equal learning opportunities (OECD, 2018).

children and young people to increase the uptake of STEM subjects and careers is key (The Committee of Public Accounts, 2018). However, efforts to increase and broaden participation in STEM education have not led to substantial changes, and inequalities persist (Smith, 2010a, 2010b).

One narrative that has guided a perception of students' lack of engagement with STEM is a deficit perspective, whereby it is assumed that students are lacking in some way (Habig et al., 2021; Mejia et al., 2018). However, this approach has been criticised for placing the responsibility onto individual students, and for failing to recognise both the structural barriers that children and young people face and the value of the assets that they bring (Godec et al., 2018; Ridgeway, 2019). Alternatively, equity-focused researchers argue that STEM education is under-serving children and young people, particularly minoritised groups, and is failing to challenge the constraints arising from the socio-cultural context in which it exists (Carlone et al., 2014). For example, Tan and Barton (2010) highlight that canonical STEM is typically represented through white, male, middle-class characteristics, which alienates those from non-dominant groups. In addition, while the majority of young people are reported to express an interest in doing science, only a minority express aspirations to work in science (DeWitt et al., 2016; Jenkins & Nelson, 2005). These issues manifest in the informal STEM learning sector as well as in formal education (Godec et al., 2021), with researchers asserting that what is valued as legitimate STEM is elitist, classist, too narrow, and leads to the erasure of different modes of science learning (Carlone et al., 2014; Dawson, 2019). A result of this is the 'Matthew effect', "where those who are already more privileged benefit in greater amounts than those who are less" (Godec et al., 2021, p. 2), therefore, engaging students in the current system is not enough as patterns of inequality will continue to be reproduced. Consequently, Godec et al. (2021) contend that that the STEM education sector owes a debt to less privileged, minoritised groups to transform the systems of exclusion.

1.2 Introducing science capital

An emerging body of research is demonstrating that children and young people's science[3] identities and aspirations can be understood and fostered through the concept of science capital (Archer et al., 2020). Science capital can be thought of as all the science-related resources available to an individual in all aspects of life, including what one knows, how one thinks, what one does, and who one knows. The concept builds on the work of Pierre Bourdieu and his theory of the reproduction of social inequalities to conceptualise science capital as science-specific forms of cultural and social capital,

[3] This dissertation will generally focus on science as opposed to STEM, in line with the majority of the science capital literature and because of the focus on primary-level education, which typically uses the label 'science' rather than 'STEM'. However, science capital has been shown to be at least a partial proxy for STEM capital (Archer et al., 2020) and so is recognised to also offer understanding in the context of STEM.

and to understand its influence on identity and aspirations through the concepts of habitus, field, and legitimation (Archer et al., 2015; a more detailed discussion of these concepts is provided in Chapter Two). The research group that established the concept of science capital through a project that is investigating young people's science and career aspirations from the age of 10 to 23 years old (Archer et al., 2013, 2020), state:

> "We are interested in the various ways that science might constitute a form of capital that can be activated and mobilised through different learning contexts to reinforce, perpetuate, or even challenge social inequalities and the ways in which shifts in the dominant values of a given field may open up, or close down, the recognition, valuing and leveraging of different forms of students' capital, to promote or restrict student engagement with science." (Moote et al., 2019, p. 3).

Since its conception, science capital research has suggested that the amount and types of science capital that young people possess is linked to how likely they are to feel like science is for them and to continue with science post-compulsory education (Archer et al., 2013). Students with higher levels of science capital are more likely to aspire to pursue science and "high achieving, middle-class students identifying as male and students with high levels of family science capital … [are] much more likely to aspire to a career in science and to feel, and be recognised by others as being, 'science-y'" (Archer et al., 2020, p. 5). Early evidence from transforming this conceptual tool into practice through the science capital teaching approach has suggested that the approach fostered more inclusive participation in science lessons, developed students' appreciation of the relevance and value of science in everyday life, and increased the proportion of students reporting a science identity (Archer et al., 2018; Godec et al., 2017).

1.3 Experiences and beliefs informing the study

The aim of this study is informed by my experiences as a recipient of widening access to science education initiatives, a science graduate, and provider of informal STEM education opportunities. I have witnessed, reproduced, and now challenge the notion that there are particular ways of engaging with science that should be privileged over others. In addition, I have observed that the delivery of formal and informal STEM education is sometimes done to, rather than with children and young people, but have also felt the barriers to enacting an equity-focused, youth-led approach. Through this study I have sought to critically reflect on my assumptions and shortcomings relating to children and young people's engagement with science and research. For example, I have expanded my intentions and echo Archer (2020) in being mindful that the focus is not necessarily on more students in STEM careers, but on helping to create a field in which children and young people enjoy feeling a rightful presence and that will serve as a vehicle to help them in whatever they want to achieve. I continuously question whether it was justifiable to engage individuals in this study when

realistically it has little power to challenge, and through my lens as a white, cisgender, able-bodied researcher, risks reinforcing systems of exclusion in STEM. This research has, at the least, informed my own theory and practice as well as discussions with other STEM education professionals. Beyond that, I hope it adds to the growing body of research, discussions, and impetus to celebrate, leverage, and build children and young people's STEM expertise to increase and broaden participation in STEM.

1.4 Impact of COVID-19

In line with a desire to conduct equity-focused and child-led research, I had originally planned a participatory research design inspired by Lundy et al. (2011), in which I had intended to work with a group of primary school children to design, implement, analyse and report on the study. However, in light of the COVID-19 pandemic, restricted access to schools, and my inexperience as a researcher, I did not feel confident in successfully harnessing the benefits and mitigating the challenges and risks associated with participatory methods. Consequently, I have tried to channel the same positionality into an adapted research design and am aware that some of my decisions may seem at odds with my worldview. I have tried to highlight instances where the study was guided by children or by child-led research, but these are much less substantial than I had originally hoped.

1.5 Research aim and questions

Given that the majority of the science capital literature is based on research with young people aged 10 years and older, which suggests that children's science aspirations are generally stable from the age of 10 and recommends building science capital in primary school (Archer et al., 2020), the aim of this study was to explore the concept with children younger than 10 years old. It cannot be assumed that the concept developed so far is applicable to this age group, therefore, it is important to first try to gain an insight into what science and being a science person means for them. Consequently, the research questions guiding this dissertation are:

1. What events do children report as being science-related in their everyday lives?
2. How do children explain why they see an event as science-related?
3. How do children explain why they see themselves or others as a science person?
4. How do children's responses vary by children's science capital index score, gender, ethnicity, and indicators of socioeconomic status?

1.6 Dissertation outline

Following this introduction to the study, Chapter Two further details the conceptual framework underlying the research, discussing key literature and its limitations, and also places this in relation to what capital is traditionally valued in science. Chapter Three outlines how a critical-constructivist and child-led approach to the research questions informed a case study design using diaries, interviews and thematic analysis supplemented by a questionnaire. Chapter Four presents the findings, including an overarching thematic network to summarise how children described science events and people in their lives, and cross-case comparisons to gain an insight into similarities and differences in children's responses. Chapter Five discusses key findings in the context of the literature available to date, the rigour of the research design and implementation, and reflects on potential implications for educators, policymakers, and families in order for more equitable STEM participation.

CHAPTER TWO: LITERATURE REVIEW

This chapter provides an overview of the literature regarding the relatively recent development of the concept of science capital and related research into STEM participation and social justice. Drawing on literature predominantly from a UK context, this review first summarises the concept of science capital, key research, and limitations. In light of this outline, dominant representations in and perceptions of STEM are discussed, with a particular focus on children and young people.

2.1 Conceptual framework

This research was inspired by the concept of science capital, which was introduced by Professor Louise Archer and colleagues as a tool to understand and explore patterns in young people's participation in STEM (Archer, DeWitt, & Willis, 2014; Archer et al., 2015). Science capital includes science-related knowledge, attitudes, experiences, and social connections, and is argued to be made meaningful by the extent to which those resources are valued in the field of science, for example, in a school science lesson (DeWitt et al., 2016). The availability of such resources, whether and how they are engaged with by young people, and their exchange value are just some of the facets captured by science capital that have been linked to the extent to which young people see science as for them or not, and the likelihood of expressing science aspirations (Godec et al., 2018). For example, surveys of 11–15-year-old students in England indicate that science literacy, family attitudes, engaging with science regularly, believing in the usefulness of science and related qualifications, and being encouraged to pursue science are related to students' intentions to participate in science and to their science identity (DeWitt et al., 2016).

The concept of science capital is derived from Bourdieu's work on the reproduction of social inequalities (Bourdieu, 1977; Bourdieu & Passeron, 1990). A key premise of this work is that individuals possess capital (cultural, social, and economic resources), which through interaction with their habitus (internalised status quo), the specific field (the context and associated norms), and the process of legitimation (valuing certain resources over others) leads to stratified levels of privilege between groups and individuals that ultimately determine their chance of success (Archer et al., 2015; Bourdieu, 1977, 1986). All of these elements — capital, habitus, field, and legitimation — work together to reproduce inequalities by affording power to the dominant group (Bourdieu & Passeron, 1990). Capital intersects with gender, class, ethnicity, and other indicators of privilege in society, and correspondingly the dominant group in science education and careers has been reported to typically be cisgender, heterosexual, able-bodied, middle-class men with high science capital (APPG on

Diversity and Inclusion in STEM, 2021; Moote et al., 2021). In this chapter, I attempt to define and discuss capital, habitus, field, and legitimation further.

Capital

The concept of capital can be described as the resources available to and accumulated by an individual that confer advantage in a society (Archer et al., 2015; Bourdieu, 1986). Capital can be economic (financial resources or resources that could be directly exchanged for wealth), cultural (embodied dispositions, objectified cultural goods, knowledge, and institutionalised qualifications), or social (membership of a group and connections), all of which can function as symbolic capital (resources that are recognised as particularly prestigious; Bourdieu, 1986). Symbolic violence, non-physical violence typically exerted towards non-dominant groups by the dominant group through the imposition of a set of norms, has been highlighted as a mechanism by which capital is reproduced (Bourdieu & Passeron, 1990). For example, Burke (2018) outlined that feeling fear or embarrassment around asking questions about scientific terminology or equipment is an example of symbolic violence because asking a question suggests a lack of capital in the context of a science class. This serves to discourage attempts to obtain such capital and feelings of belonging, and encourages those with capital to accrue more through their comfort in being able to engage. The effects of symbolic violence can be masked by agency, such that an individual student is perceived, and may believe themselves, to have made an autonomous decision that science is not for them (Burke, 2018).

Archer et al. (2015) argue for a re-thinking of capital to include scientific forms of cultural and social capital in order to reflect contemporary society. Considering UK government policy, the emphasis over past decades on science for a productive and innovative economy indicates the increased value being afforded to the field (Hoskins & Barker, 2020). Furthermore, Archer et al. (2015) highlight the role that scientific literacy can play in affording privilege through individual social agency and power. Consequently, a social justice approach to science education is critical in order to challenge the people and structures with power to look beyond the dominant group, for example, by broadening what resources are considered legitimate and valuable (Archer et al., 2021; Godec et al., 2018). This study aims to facilitate this by investigating what children themselves deem to be science-related and valuable in their everyday lives. This knowledge could then be used to challenge dominant actors within the field to broaden the norms within their science-related context, thereby minimising symbolic violence and facilitating the development of science and other forms of capital.

Habitus

Habitus can be described as a set of entrenched dispositions that are the product of the structures of the environments that an individual inhabits, which lead to personal, embodied structures that guide an individual's actions, attitudes and general way of being (Bourdieu, 1977). Groups of individuals who are products of similar conditions, for example, of the same social class, are likely to acquire similar dispositions for viewing and conducting themselves in the world (Bourdieu, 1977). In addition, habitus reinforces and reproduces itself, as Bourdieu (1977, p. 87) explains:

> "for example, the habitus acquired in the family underlies the structuring of school experiences (in particular the reception and assimilation of the specifically pedagogic message), and the habitus transformed by schooling, itself diversified, in turn underlies the structuring of all subsequent experiences (e.g. the reception and assimilation of the messages of the culture industry or work experiences), and so on".

In this way, habitus serves to frame what individuals see as possible or unthinkable for people like themselves. Indeed, differences in the distribution of capital and in family habitus for children from different social classes has been linked to classed and racialised differences in science aspirations (Archer et al., 2012).

In this study, an insight into the social class structures that contribute to an individual's habitus is obtained through demographic data, while children's diaries as well as their responses to questionnaire and interview questions provide insight into other habitus-producing environments, for example, their family and home life. These indicators enable comparisons to be made to suggest whether habitus shapes how children from similar groups categorise science-related events and people. A key motivator for this research is the desire for less children to see science as inconceivable, therefore, understanding habitus and factors that lead children to internalise the idea that science is not possible or desirable is invaluable (Godec et al., 2018).

Field

Fields can be understood as contexts with explicit and implicit norms and expectations (Bourdieu & Wacquant, 1992; Godec et al., 2018). For example, a field may be a science club and encompass who one expects to lead and attend the club, what one expects to do, how one is expected to behave, and what one is expected to know. Fields determine the value of capital within them, and so capital — and habitus — should always be considered in relation to a field (Bourdieu & Wacquant, 1992). Individuals can succeed by following the rules of the field, that is by having the resources and dispositions to engage in ways that are valued by that field (Bourdieu & Wacquant, 1992; Burke, 2018). Bourdieu discusses that the limits and rules of the field are not fixed, they can be challenged and change, most likely by dominant members to increase the value afforded to the types of capital they possess and to de-value others (Bourdieu & Wacquant, 1992). Burke (2018) highlights that it

takes time for individuals to respond to a change in the rules of the field and that this lag is prolonged for non-dominant members. Consequently, from a social justice point of view, a key target is to change the rules of the field to broaden what is valued, while centring the least dominant members (Archer, 2020). This research aims to gain a child-led insight into how children engage with science in their everyday lives to facilitate a discussion around how this is valued and to inform how the rules of the field of STEM education could be challenged in order for more students to feel like science is for them.

Social justice academics are working to play the field at its own game. Research groups such as the STEM Participation and Social Justice Research group led by Professor Louise Archer have created a body of work that aligns with what is valued in the field of education research and academia, for example, peer-reviewed articles[4] and policy briefings[5], but that challenges what is valued in the field of STEM education (Archer et al., 2021; Dawson, 2019; Godec et al., 2018). This work has gained recognition, for example, by the Office for Standards in Education, Children's Services and Skills (Ofsted, 2021), professional societies (Kirby-Green, 2017), community organisations (STEMettes, 2014), science centres (Hawkins, 2017), and schools (Tsui, 2018). Encouraging the field to value a social justice approach to STEM education should then afford power to those with related capital to change the rules and further broaden what is valued.

Legitimation

Legitimation is the process by which value is given to capital. This must also be determined in the context of the field, as Archer et al. (2015, p. 925) explain: "the most powerful forms of capital will be those whose intrinsic value can be most readily and precisely converted into symbolic forms that match the requirements of the field". For example, children and families may consider cooking to be scientific at home, but this may be valued as less scientific in the context of school science than, for example, going to a science club. The requirements of the field typically reflect and reproduce the needs and values of the dominant group (Godec et al., 2018), which serves to perpetuate the idea that there are 'correct' or 'best' ways to engage with science. Individuals may possess a range of alternative non-dominant resources or capital, but if they are not considered legitimate in the field, they will afford only limited advantage (Godec et al., 2018). This research explores whether the science events and science people reported by children in their everyday lives aligns with the dominant representations of science and science people that are considered legitimate in science education.

[4] https://www.ucl.ac.uk/ioe/departments-and-centres/departments/education-practice-and-society/aspires-research/publications

[5] https://www.ucl.ac.uk/ioe/departments-and-centres/departments/education-practice-and-society/aspires-research/summary-reports-and-books

Interaction

The four elements discussed above interact to generate a hierarchy of privilege and disadvantage (Archer et al., 2015; Yang, 2014). For example, students who are close with a family member who has a skilled science-related job (social capital) are more likely to experience a home environment (and habitus) that values science, which is likely to translate to positive science attainment and aspirations (symbolic capital), and may be reinforced by their family being able to spend time and money (economic capital) on science enrichment activities that are valued (through legitimation) in science education (Archer et al., 2012, 2015; Quaye & Pomeroy, 2021). All these factors open doors to similarly privileged careers and lifestyles (Archer et al., 2015), which facilitates the reproduction of power for those that have access to and are able to leverage resources that are considered legitimate within the field.

2.2 Key science capital research

The science capital concept has been developed and is continuing to inspire research projects by the STEM Participation and Social Justice Research group. This section highlights key developments, findings, and tools produced by this group that are related to this dissertation research, with a particular focus on research closely related to science capital but also drawing on some of their broader social justice work.

From their initial iteration of the concept of science capital, Archer et al. (2015) have consolidated the following eight dimensions of science capital: scientific literacy; science-related attitudes, values and dispositions; knowledge about the transferability of science qualifications; science media consumption; participation in out-of-school science learning contexts; family science skills, knowledge and qualifications; knowing people in science-related roles; and talking about science in everyday life. These dimensions have been used to create a survey instrument that serves as an index of science capital, which has been validated with young people aged 10–18 years (Archer et al., 2015; DeWitt et al., 2016; Moote et al., 2021). In this study, the dimensions of science capital are used to inform the data analysis, and the findings are discussed in relation to the extent to which they align with the identified dimensions and index of science capital.

The science capital index has been developed and implemented alongside student interviews as part of the ASPIRES research project[6], a longitudinal study that is tracking young

[6] https://www.ucl.ac.uk/ioe/departments-and-centres/departments/education-practice-and-society/aspires-research

people's science and career aspirations from age 10–23 years. Key findings from the available literature to date, from research with 10–19 year olds (Archer et al., 2020), include:

- Young people did not lack career aspirations and these aspirations were generally stable from 10 years old. However, a relatively small proportion of young people aspired to be a scientist and the demographic profile of this group became less diverse over time. There is no evidence to suggest that the relatively low level of science aspirations is due to low interest in science, families not valuing science, or negative views of scientists.
- Young people identified as having high science capital were more likely to express a science identity, and to aspire to and pursue post-compulsory science education, and a science-related career.
- Young people's science capital, aspirations, and identity were shown to be patterned by inequalities related to attainment, class, gender, and family science capital that were evident at age 10 years and worsened over time. Considering ethnicity, South Asian and Chinese young people were the most likely to express science aspirations. Black students reported relatively high science aspirations and identity, but these were not found to translate to post-compulsory science education and careers.
- Young people associated science with masculinity and cleverness, which negatively impacted many young people's science identity and aspirations, especially among girls.
- A teaching approach for secondary school teachers based on the science capital concept has shown positive impacts for students, for example, on science identity, and engagement in lessons (Godec et al., 2017).

Overall, the authors found many interacting factors that influenced young people's science identities and aspirations and they consequently advocate for an equity-focused transformation of STEM education that focuses on changing the field rather than young people by building science capital, addressing exclusive educational practices, and challenging dominant representations of STEM.

The research group has since extended their work to explore equity in informal STEM settings (designed and community spaces) through the Youth Equity + STEM project[7]. Key findings from their work with 11–14 year olds (Archer et al., 2021; Godec et al., 2021) include:

- Participation in informal science education was highest among white and the most socioeconomically advantaged young people.
- Interest in STEM did not clearly correlate with participation in informal STEM education. Young people that were reported to be under-served by informal science education

[7] https://www.ucl.ac.uk/ioe/departments-and-centres/departments/education-practice-and-society/youth-equity-stem

(interested and engaged in everyday science but not in designed and community science spaces) were disproportionately more likely to be from minoritised groups and categorised as having lower levels of dominant forms of science and cultural capital.

- Equitable outcomes, for example, transforming inequalities in STEM capital and aspirations, were facilitated for minoritised young people through framing science learning in the context of what matters to them; challenging dominant ideas of who and what is valued, and how science is taught and engaged with; supporting young people to challenge the field of STEM themselves; and recognising and providing opportunities for young people to leverage their lived experiences.

Consequently, the authors argue against a common perception that non-participation in informal science education is due to lack of interest, and instead that it is a result of exclusionary practices, such as inaccessibility and lack of representation of diverse communities, and structural inequalities, such as certain groups of young people having to prioritise how they spend their out-of-school time according to the greatest predicted gains for the future, in ways that more privileged young people do not have to.

The research presented in this dissertation builds on the research discussed above by exploring whether and how young children's science identity and aspirations are related to the science events and people they see in their everyday lives, if there any indications of patterns of inequalities, and how the findings can inform practice across formal and informal science settings.

2.3 Limitations of the science capital concept and research

This section discusses gaps in and potential limitations of the science capital research that have informed the research aims and questions of this study. First, a key gap in the literature is that the available research to date has been conducted with children and young people aged 10 years old and above in predominantly school science and informal science settings. A Primary Science Capital research project is currently underway, however, it is focused on working with practitioners to develop a primary science capital teaching approach, rather than working with children directly[8]. As Archer and colleagues have already identified in their previous work, children's science aspirations and feelings of whether science is for them are present and persist at least from the age of 10 years and "evidence indicates that life-world experiences prior to 14 are the major determinant of any decision to pursue the study of science" (DeWitt et al., 2013, p. 1038). Consequently, understanding

[8] https://www.ucl.ac.uk/ioe/departments-and-centres/departments/education-practice-and-society/stem-participation-social-justice-research/primary-science-capital-project

the role science and science capital plays in the lives of children younger than 10 years old could reveal novel and/or earlier opportunities for more equitable STEM education.

A study by Padwick et al. (2016) developed an adapted version of the science capital index for 7 –11 year olds and found evidence to support the ASPIRES research in that children reported perceiving scientists as clever and hard-working, and the attributes that children with high science capital identified with aligned more closely with the attributes that they associated with scientists compared to other groups of children. This was echoed by research with 6–9-year-old low-income African American children, which found associations of school science and being a scientist with doing school, smartness, and effort, but also with being caring and having power and status, demonstrating that young children develop complex relationships with science at this age (Varelas et al., 2011). While these studies capture some facets of science capital from the perspectives of young children, they are missing insight into everyday science settings. Indeed, despite recognising everyday contexts in the dimension of science capital that encompasses engagement in out-of-school settings, the work by Archer and colleagues so far predominantly covers school science and informal science settings, with the latter focusing on designed and community spaces. In light of the influence that family capital has been suggested to have on children's attitudes and outcomes (Archer et al., 2012), as has been starkly highlighted during the COVID-19 pandemic (Sevilla et al., 2020), there is a need to explore the perceptions, value, and power of science in the everyday contexts of young children's lives.

Second, the concept of science capital and particularly the index have been criticised for being reductive. Deriving the concept and index from young people's agreement with pro-science statements and what is dominantly associated with science identity and aspirations risks reinforcing dominant values and "reifying "science" and scientific institutions as they currently *are* (i.e., exclusionary along gender, class, and ethnic lines)" (Jensen & Wright, 2015, p. 1145). The science capital research team have since critically discussed the role that field plays, rather than placing the responsibility on individuals to simply respond more positively, and included open-ended questions in an attempt to reduce the implication that there are 'correct' forms of science engagement (Godec et al., 2021). Consequently, it is important to use the science capital index with caution. The authors themselves highlight that the index is to be used to complement qualitative insights (DeWitt et al., 2016). In addition, the concept and index must be flexible, regularly validated, and broadened where necessary, particularly if efforts to make science participation more equitable are successful, to ensure it continues to align with "science-related cultural and social resources which, empirically, would seem to be endowed with the most value in relation to the field of science education, particularly in relation to promoting science participation" (DeWitt et al., 2016, p. 2434).

Third, Bourdieu's theory of social reproduction has been criticised for being pessimistic, deterministic, and failing to account for how transformation of or resistance to inequitable systems can be possible (Mills, 2008). Indeed, if fields and legitimation are resistant to change, or even incredibly slow to change, could it be misleading to promote that children engage in science in ways that are not (yet) valued by those with power, such as educational institutions? Moreover, where upward social mobility has occurred, research suggests this experience can be traumatic due to cleft habitus, where habitus is split over two fields leading to discomfort and hyper-awareness of 'inappropriate' behaviours in both fields (Burke, 2018; Yang, 2014). However, theory and research suggest that challenging social reproduction in STEM education is possible and positive, particularly when the field is challenged rather than individuals. For example, Mills (2008) discusses alternative or overlooked readings of Bourdieu's theory, such as that while fields are constraining they are also dynamic, not static nor eternal, areas of struggle where hierarchies are continually tested. Mills (2008, p. 83) provides support for Archer et al. (2021), by arguing that "while teachers should endeavour to develop in students a sense of transformatory possibility, they should be more concerned to transform schooling". This call extends beyond teachers to all dominant groups, and while the majority will, according to Bourdieu's theory, work to conserve the existing distribution of capital, there is space for other dominant and non-dominant members to subvert the systems (Mills, 2008). Yang (2014, p. 1536) contends that:

> "It is very likely to be true that, in certain fields, the 'interrupters' may not be able to overtake those who traditionally rule that field in the near future, but they bring in a new dynamic. When the deviations are no longer the minority, they will become a trajectory."

In the context of two informal STEM education settings in the UK, practices were identified that led to equitable outcomes for young people from communities traditionally underrepresented in STEM and were particularly successful when strongly underpinned by challenging and broadening who and what science is represented and how STEM can be engaged with (Archer et al., 2021).

Taking all the above into account, this research focuses on science in everyday contexts in the lives of 8–10-year-olds, which can inform how the science capital concept and index might benefit from being adapted for primary-school-aged children, and how science education fields can broaden who and what counts.

2.4 Who and what is valued and represented in the field of science?

To better understand the constraints set for children in science settings by capital, habitus, field and legitimation, this section highlights literature discussing who and what is valued, represented, and excluded in science, and how this is reflected in research with young people. First, evidence suggests that middle and upper classes are dominantly represented. Henry et al. (1988, p. 142) assert that

"the school assumes middle class culture, attitudes and values in all its pupils". This has been shown by Dawson (2019) to be reflected in who participates in informal science learning, with the minority from non-white lower classes and the majority being middle-class people living in cities and engaging through their family or school. As touched on earlier in this chapter, this pattern of inclusion can be misrepresented (by outsiders and by individuals themselves) as a result of meritocracy or agency. Research with secondary students and teachers (Lardier et al., 2019; Owens & de St Croix, 2020), and women working in STEM (Bird & Rhoton, 2021; Cech & Blair-Loy, 2010) has suggested that while some individuals recognise structural barriers, there remains a pervasive narrative that access to and/or success in science settings is determined by personal attributes such as aptitude, attitude, and effort. This narrative has been argued to be perpetuated by educational gatekeeping practices such as schools in England being encouraged to only select high-achieving students to take 'triple science' (three separate GCSEs in biology, physics, and chemistry) that has been afforded high status by government and industry (Archer et al., 2017). This aligns with children's perceptions as research has shown that canonical science and scientists are often described as clever, hard, and hard-working, with scientific knowledge seen as powerful but also inaccessible (Archer et al., 2020; Gonsalves et al., 2021; Padwick et al., 2016; Varelas et al., 2011). Moreover, recent research with primary school pupils has shown that the association between science and intelligence persisted in the long-term, despite a disruption in the short-term, following an intervention that was designed to showcase diversity in working scientists and the skills required for science-related careers (Shimwell et al., 2021).

Second, the prevailing image of a scientist by young people has been shown to generally be a middle-aged man (or older) in a laboratory wearing a white coat (Avraamidou, 2013; Finson, 2002; Mead & Métraux, 1957). This representation has been suggested to have been unchallenged and, consequently, exacerbated at an institutional level in the UK. Newton & Newton (1998) demonstrated that the introduction of the English and Welsh National Curriculum Order for Science in 1989 failed to change primary children's perceptions of a scientist. In addition, Trew et al. (2021, p. 18) suggest that the 2013 National Curriculum for primary education (Department for Education, 2013) reinforces the stereotype of an older white male scientist in a white coat because "its non-statutory guidance suggests some scientists who could be studied: 13 males and 2 females, mostly white, mostly European, and all dead except one". A more recent report on the issues impacting children's primary science learning has also identified that despite teachers increasingly using contemporary examples of science and living scientists, stereotypes remain in school displays, library books, and lesson resources (Bianchi et al., 2021).

Third, canonical science is associated with school science and does not value everyday science. Indeed, the report by Bianchi et al. (2021) highlights the issue that primary science learning is not relevant to children's lived experiences, resulting in them seeing science as predominantly school-based and not transferable to their other day-to-day experiences. Research with secondary-school-aged girls found that while out-of-school-time (OST) activities were temporarily successful in re-figuring their worldview of science in ways that included their everyday experiences and encouraged them to consider themselves as insiders, this narrative that school science was 'real science' was resistant to change in the long-term (Gonsalves et al., 2013). Interestingly, even when encouraged and validated in an informal science setting, the authors noticed that "while youth are likely to bring cultural models from school science into OST spaces, they are less likely to see the newly re-figured worlds of science and their associated cultural models as powerful or legitimate in their science classrooms" (Gonsalves et al., 2013, p. 1091), highlighting the strength of the legitimation of formal science education. Research with primary-school-aged children indicates that the association of science with school goes beyond specifically science-related content and includes 'good' behaviours intertwined with 'doing school' more generally, such as, listening to teachers and focusing on classwork (Varelas et al., 2011). Moreover, Godec et al. (2021) suggest that this de-valuing of everyday science is also a narrative promoted in informal science education, whereby many young people reported participating and having significant expertise in everyday science-related activities, such as gaming, but that this was not necessarily able to be leveraged in informal science settings.

Finally, the field of STEM education has been criticised for not valuing non-dominant types of capital that young people gain from their communities, which Yosso (2005) has termed 'community cultural wealth' and is typically held by minoritised groups (Habig et al., 2021). This lack of recognition has been to shown to impact the language that the field prioritises, that is, academic language that privileges dominant cultural groups (Claussen & Osborne, 2013), and even the type of data that is collected to assess who is participating, as Dawson (2019, p. 50) explains: "we know more about who visits science centres than we do about who takes part in community-led science activities or watches science-related television at home, and that knowledge is marked by structural inequalities". Archer et al. (2021) and Scott (2014) have highlighted the powerful influence that valuing youth-centred views and identities in the development of 'contextually authentic' science education experiences can have on students' relationships with science. The authors both found that broad exposure to scientific work in practice and superficial connections to young people's interests were not enough to positively impact students, but approaches that incorporated individual

students' experiences, and enabled them to explore and define for themselves what was relevant and valuable in their experiences were much more successful.

2.5 Summary

The concept of science capital offers a lens through which to understand young people's participation in science education. It builds on Bourdieu's theory of social reproduction to show how the elements of capital, field, habitus and legitimation interact to perpetuate the status quo of who and what is valued in science. Those who are dominantly represented and perceived as being scientists have been shown to be white middle-class men in white coats, who are intelligent and good at school. Research into science capital has demonstrated that it is possible to challenge these representations and encourage a broader valuing of different types of capital held by young people, however the majority of this work has been carried out with secondary-school-aged students in school and informal science settings. Consequently, there is an opportunity to contribute to the gap in science capital research with primary-school-aged children by gaining an insight into science in their everyday lives to try and understand their capital, habitus, and personal process of legitimation.

CHAPTER THREE: RESEARCH DESIGN AND METHODOLOGY

The preceding chapters have outlined a gap in the literature, whereby the concept of science capital has not yet been explored with young children (here defined as under the age of 11 years old) to the same extent as with older children. This chapter outlines how the research design was informed by my philosophical approach to the research questions to contribute to addressing that gap. The choice and implementation of largely qualitative data collection methods and analysis, as well as considerations relating to ethics and limitations of the methodology are also discussed.

3.1 Research design

When making methodological decisions, a flexible, pragmatic approach was taken, partly due to the restrictions around conducting research in person because of the COVID-19 pandemic, and partly because I see science capital as a useful but superficially imposed construct for potentially more complicated realities. I believe it is impossible to completely capture these realities, but that some methods are better suited to gaining an insight than others.

3.1.1 Philosophical approach

This research was conducted from a worldview engaged with constructivism and critical theory. From a constructivist perspective, "realities are apprehendable in the form of multiple, intangible mental constructions, socially and experientially based, … and dependent for their form and content on the individual person or groups holding the constructions" Guba & Lincoln (1994, p. 110). Constructivist research aims to gain an understanding of these constructions that have been developed through lived experiences by interpreting participants' perceptions (Lincoln et al., 2018). The constructivist lens also applies to the researcher: we cannot separate ourselves from our realities, therefore, how the researcher understands others is linked to their own constructed realities and interactions with participants (Angen, 2000). This approach aligns with the research questions as they aim to generate an understanding of children's perspectives of science in the context of their lived experiences. It also fits with the emphasis placed on the research being child-led as control is not placed solely with the researcher, but is shared with participants (Lincoln et al., 2018). Qualitative methodology is also closely aligned with this approach as it facilitates the exchange of ideas and interpretations between participants and researcher that are important to "collaboratively construct a meaningful reality" (Lincoln et al., 2018, p. 118).

This research aims to go further than understanding children's perspectives and informing practice, and endeavours to critique systems of power within the field of science (Barton, 1998). As a

result, a perspective engaged with critical theory is key as it draws on the belief that this study is situated in a world involving "interactions of privilege and oppression that can be based on race or ethnicity, socioeconomic class, gender, mental or physical abilities, or sexual preference [or other non-dominant characteristics]" (Lincoln et al., 2018, p. 114). It is important to both study the experiences of children living among the current social systems and to learn from historical perspectives to generate knowledge that can change existing structures of oppression (Lincoln et al., 2018). This approach aligns with the research questions as they aim to use an understanding of children's lives to explore and challenge the identities and resources that are valued in the field of science. As with constructivist research, control is shared between researcher and participant, facilitating a focus on children making decisions as to how they would like to take part (Lincoln et al., 2018). Qualitative methodology is considered to be a good fit for critical research as it is "well suited for locating the *meanings* people place on the events, processes, and structures of their lives … and for connecting these meanings to the *social world* around them" (Miles & Huberman, 1994, p. 10) and also for exploring misapprehensions (Guba & Lincoln, 1994). Transforming the equity of science education is beyond the scope of this study, however, it is hoped that the research can be used to inform educators and policymakers for more equitable practice.

3.1.2 Research with children

From the outset, this research was driven by a desire to be child-led. I reflected on my own experiences working with children and sought out literature that emphasised children's agency, prioritising research in which children gave their perspectives on how they would like research to be conducted with them. Consequently, the design of this research aimed to foreground the following considerations (Hill, 2006): fairness, effectiveness, agency, choice, openness, diversity, satisfaction, and respect. I saw each child as an expert on their own lives and endeavoured to offer a research experience that supported children's expression of their perspectives, abilities, autonomy and power (Clark, 2010; Kellett et al., 2004). However, I recognise that as the researcher and final communicator of the data, the research is primarily channelled through me and I must critically reflect on the role I play in collecting and representing children's perspectives (Spyrou, 2011). Moreover, I use the term 'child-led' cautiously, as the methods are still framed to serve my own understanding and therefore risk being constrained by and reinforcing dominant adult perceptions of children (Hunleth, 2011).

3.1.3 Study outline

The research was conducted as a qualitative case study with multiple cases (Yin, 1994) whereby data were collected with a small number of children via a number of tools in their own time over a period of days or weeks. This study follows the definition of case study research given by Creswell (2013, p. 97):

> "a qualitative approach in which the investigator explores a bounded system (a *case*) or multiple bounded systems (cases) over time, through detailed, in-depth data collection involving *multiple sources of information* (e.g., observations, interviews, audiovisual material, and documents and reports)".

A case study design was chosen because it "allows an investigation to retain the holistic and meaningful characteristics of real-life events" (Yin, 1994, p. 3). Children's everyday lives are key to the research questions as a full understanding of an individual's science capital is incomplete without an understanding of their life as a whole. Case studies facilitate the capture of children's science-related beliefs across all parts of their lives that they are willing to share by reducing the need to limit variables or context and by embracing multiple sources of evidence that can be triangulated (Yin, 1994). Correspondingly, a holistic approach was taken to study each case as a whole (Punch & Oancea, 2014), with the aim to capture different, possibly overlapping, aspects of children's lives with different data collection tools. Moreover, a strength of qualitative research and case studies in particular is the capacity to address the explanatory elements of research questions (Merriam & Tisdell, 2016; Yin, 1994), therefore, this strategy was considered appropriate to address both the 'what' research questions and how children explain why experiences or people are seen as 'science-related'.

A multiple case study design was chosen with each child treated as a case during data collection and analysis. Originally, the aim was to study theoretical replications, whereby each case "produces contrasting results but for predictable reasons" (Yin, 1994, p. 46) by comparing cases that differed demographically and/or scored significantly differently on the science capital index. However, due to a small number of respondents, convenience sampling was adopted instead of purposive sampling and all respondents were accepted as cases. There was a lack of variation between participants based on demographics and science capital index score, therefore, literal replications were investigated, whereby each case is predicted a to give a similar result (Yin, 1994). This study is exploratory so the exact nature of the predicted result was undefined, but theoretically expected to be similar. In addition, multiple cases were chosen as a larger number of cases can lead to, but is not necessarily essential for, a greater level of certainty about the findings (Merriam & Tisdell, 2016).

3.2 Participants

Children aged 8–10 years old were recruited for the case study through both convenience and snowball sampling (Miles & Huberman, 1994). Initially, a convenience sample of approximately 30 primary schools in South East England that were already known to the researcher were emailed asking them to show children a short video about the study and to send an information sheet to parents/guardians (Appendices A–C). This method of recruitment was employed as using personal networks has been shown to be successful when working with children (Foss et al., 2013). Two children and their guardians were recruited in this way. An additional child and their guardian completed consent forms but did not contribute any other data and have not been included in this report. Recruitment was then extended by contacting a mailing list targeted at UK education and research communities asking recipients to share the recruitment message and information video with any partner schools and relevant contacts (Appendix A). This resulted in a snowball sample of an additional two children.

Attempts were made throughout the recruitment process to respect children's agency. It was requested that teachers ideally present the information video to children at school before sending the message home to guardians so that children could consider taking part before discussing with parents/guardians. Similarly, while schools were closed due to the COVID-19 pandemic, guardians were encouraged to first watch the information video with their children before reading the information sheet to encourage children to feel that the decision to take part was directed primarily at them. The order of questions in the consent form (and questionnaire) were deliberately arranged so that questions for children generally came before questions for guardians. An information video rather than written information was created for children as some have reported preferring to listen instead of read (Hill, 2006), as well as to try and build a relationship with children. Informal feedback from guardians and teachers suggest that this was successful.

The final case study was conducted with four children, which was considered acceptable in order to manageably study the data in depth, and to facilitate cross-case comparisons (Miles & Huberman, 1994). Demographic information, children's level of science capital according to their score on the science capital index, and which sources of data were collected are outlined for each participant in Table 1.

3.3 Data collection

Children and their guardians were asked to complete a questionnaire and children were asked to create a diary of science-related events. They were also invited to take part in an optional online interview or to complete an offline alternative. Recruitment strategies and data collection tools

were initially developed with feedback from primary school teachers and then tested with two schools in a pilot study, which recruited one participant. Final developments were minimal and so the data from the pilot study has been combined with data from the main study (and included in Table 1). This section reviews the design and implementation of each of the individual data collection tools.

Table 1 | Demographic information, science capital index quantile, and sources of data collected for each participant

	Demographic information						Data collected			
Pseudonym	**Gender**	**Age (years)**	**Ethnicity**	**IoD2019 decile**	**Eligibility for PP/FSM**	**Science capital**	**Q**	**D**	**I**	**IA**
Josh	Male	8	White British	7	No	High	✓	✓	✓	
Ava	Female	8	White British	8	No	Medium	✓	✓		✓
Ethan	NC	NC	NC	NC	NC	NC		✓	✓	
Ollie	Male	10	White	8	No	Medium	✓	✓		

Note: IoD2019, English indices of deprivation 2019 (where 1 = most deprived 10% of neighbourhoods in England and 10 = least deprived 10%); PP, pupil premium; FSM, free school meals; Q, questionnaire; D, diary; I, interview; IA, interview alternative; NC, not collected (this participant chose not to complete the questionnaire).

3.3.1 Questionnaire

The first task for participants was a cross-sectional online questionnaire via the university-approved platform, Microsoft Forms (Appendix D). The questionnaire was designed to contribute to exploring how children's attitudes, behaviours and sociodemographic information may be connected to who and what they see as science-related and why. In addition to within-case analysis, the questionnaire facilitated cross-case comparisons between responses to standardised questions (Sutton, 2011). To inform to what extent the concept of science capital is applicable to primary-school-aged children it was also considered pertinent to assess children's responses to items used in science capital research, including the standardised science capital index (DeWitt et al., 2016).

The first section of the questionnaire consisted of five attitudinal items, taken from the 2016 version of the full science capital survey (J. DeWitt, personal communication, November 13, 2018), to give an indication of children's science identity, perception of science, and science aspirations. Responses were measured on a five-point scale from 'strongly agree' to 'strongly disagree' with 'neither agree or disagree' as a middle point. The second section of the questionnaire comprised the short 14-item index that has been validated to calculate 11–16 year olds' science capital score (Archer et al., 2015; DeWitt et al., 2016; Moote et al., 2021). Further details of the scoring are provided in section 3.4.1. For questions measured on the five-point scale it was considered useful to

add the option of 'I do not know' to separate it from 'neither agree or disagree' as a potential indicator that the item may not be relevant for this age group (Krosnick & Presser, 2010) as the questions have not been validated with children younger than 10 years old. The remaining questions for children asked for their school, age, and gender. The final section of the questionnaire asked guardians to complete optional questions to provide children's ethnicity, eligibility for free school meals/pupil premium, and postcode. This was to facilitate connections with the literature, which has suggested that science capital is patterned by gender, ethnicity and socioeconomic status (Archer et al., 2015). Asking for children's gender was deliberately designed as an open-ended rather than a multiple-choice question to prioritise inclusivity, and following the pilot, was moved from the consent form to the questionnaire to avoid participants feeling obligated to provide this information in order to take part in the research.

3.3.2 Diary

In the second stage, children were asked to create a diary for at least one day and up to seven days of anything in their day that they considered to be related to science. The use of diaries was inspired by three pieces of research. First, the STEMwhere app developed by Morris et al. (2019), through which children aged 7–14 years old could check in when engaged in STEM activities. In contrast to Morris et al. (2019, p. 45) who excluded activities "that scientists and educators would not consider to be STEM", this study wanted to centre children's decisions over what is considered STEM and compare them to traditional judgements. Second, in a study by Varelas et al. (2011) children aged 7–9 years old were encouraged to regularly write and draw in science journals, which were then used as prompts in conversations about children's science identities. Third, inspiration was taken from Zimmerman & Bell (2014) who found that asking 'when is science?' was easier for children and seemed to better reflect their engagement with science than asking more direct questions such as 'what is science?'.

The researcher suggested that diaries could be created by taking photos, recording audio, or by writing, but encouraged children to take the lead. Guardians were invited to send diary entries to the researcher by email or WhatsApp whenever suited them. For the main study, it was not required that diaries be created on consecutive days. However, for the pilot study, participants were asked to create diaries for seven consecutive days. This was intended to try and capture a 'typical' week, rather than relying on a daily snapshot to be representative of children's lives, but was later considered to be a high demand on participants' time and memory. For the main study children and guardians could decide the extent to which they engaged with the diaries.

The defining characteristics of a diary, as provided by Alaszewski (2006), were considered ideal for answering this study's research questions. "Entries record what an individual considers relevant and important" (Alaszewski, 2006, p. 2), prioritising authenticity and children's freedom to present what they see as science-related. This was reinforced by children being the primary owners of the diaries, having created them in their own space, and access to the researcher was given by their consent (Dockett et al., 2017). In addition, diary entries are intended to be regular and contemporaneous, which helps to prevent issues with recall and to capture facets of life that are taken for granted or usually unnoticed (Alaszewski, 2006). Diaries also allowed time for unpressured participation that could then serve as prompts for exploration using other methods, such as an interview (Bartlett & Milligan, 2015).

The decision to recommend that guardians use WhatsApp and/or email to transfer children's diary entries was intended to be straightforward and flexible. While the transfer of diaries was digital, it was made clear that the diaries themselves need not be. Indeed, several participants chose to create a pen-and-paper diary, which was then photographed. According to Ofcom (2020), the majority of households and adults in the UK use the internet at home and a smartphone, and are increasingly using services such as WhatsApp. While this suggests that communication via email and WhatsApp is familiar and accessible for many, it is important to recognise that the choice to use internet-/smartphone-based methods disadvantages or excludes some of the population, who are disproportionately from groups of a lower socioeconomic status (Ofcom, 2020).

3.3.3 Interview

In addition to the questionnaire and diary, children were invited to take part in an optional interview via Microsoft Teams, during which the audio was recorded and then transcribed manually, or an offline alternative. An interview schedule, example visual prompts, and an example of the offline interview activity worksheet are provided in Appendices E–G.

For the online interview, children were first asked whether they thought a selection of pre-defined activities are related to science and why. The activities were taken from research by Zimmerman & Bell (2014) as they had been shown to be appropriate for primary-school-aged children. Next, children were shown a selection of their diary entries and asked specific questions to explore the diaries further and/or clarify any aspects that were unclear. Questions were then asked to investigate what children associate with being a science person using items from the questionnaire as prompts. Finally, an online card-sorting task was used for children to sort prompts into categories according to whether they thought they were important, not important, or do not really matter for being science a person. The prompts were taken from the science capital index

(DeWitt et al., 2016) to explore whether the children in this study valued the same aspects as the index.

A semi-structured interview design was chosen to allow for children's responses to be explored and to customise the interview to the individual while also ensuring that particular topics of discussion were covered and could be compared between cases (Cohen et al., 2018). Inspiration was taken from photo-elicitation interviews by using photos and other participant-produced prompts to ground the interview in children's perspectives and self-expression and help overcome any memory blocks (Eder & Fingerson, 2001; Pyle, 2013; Scott, 2014). Visual prompts, such as digital sticky notes, were used throughout the interview as an aid if needed to give children time and mental space to think, and to try and make it more interactive and enjoyable (Cohen et al., 2018).

For the pilot study, participants were asked to consent to an interview as part of the whole study in the hope of gaining as full an insight into science in children's lives as possible, as well as to practice the implementation of all possible data collection tools. However, due to feedback that the thought of an interview was potentially daunting for some children, the interview was made optional for the main study and an offline alternative was developed. The offline version asked largely the same questions and was formatted as a printable or online worksheet with space for children to write, type, or draw their responses.

While acknowledging that the power differential between researcher and participant can be impossible to equalise (Eder & Fingerson, 2001), attempts were made to mitigate the potential unfamiliarity of the interview situation and to put children at ease as much as possible (Cohen et al., 2018). For example, children were reminded that no answers would be wrong, that they could stop or take a break at any point, and were encouraged to say if anything was unclear or they wanted to move on. Notes were taken throughout the interview that could be seen by both the researcher and the interviewee, and children were invited to correct these notes as a form of real-time member checking (Chua & Adams, 2014). At the end of their participation, children and guardians were invited to receive a certificate to thank them for taking part.

3.4 Analysis

This section reports how data from the questionnaire, diary, interview and interview alternative were analysed. Individuals' responses to the questionnaire were treated as a unit of analysis. Data from the diary, interview and/or interview alternative were analysed together for each case and also pooled to analyse the data collectively across all cases.

3.4.1 Questionnaire

Responses to the science capital index items were analysed to give each child a science capital score. A full list of the items and how responses are scored is presented in Appendix H. For example, responses to the item 'It is useful to know about science in my daily life' are scored on a 5-point scale from -1 for 'strongly disagree' to 1 for 'strongly agree' (Moote et al., 2021). Scores for each item are summed to give a raw score ranging from –22 to 31.5 and then transformed to a scale of 0–105 (DeWitt et al., 2016). Transformed scores are then divided into three quantiles representing low (0–34), medium (35–69), or high (70–105) science capital (DeWitt et al., 2016).

Children's responses to items regarding science identity, perceptions, and aspirations; age; gender; ethnicity; eligibility for free school meals/pupil premium; and postcode information were used to facilitate cross-case comparisons and to compare to the science capital literature. Postcode data was used as an area-level indicator of socioeconomic status according to the English Indices of Deprivation 2019 (IoD2019; Noble et al., 2019). The IoD2019 explorer (http://dclgapps.communities.gov.uk/imd/iod_index.html) was used to obtain a summary of how deprived the postcode area is relative to all other areas in England, where 1 is the most deprived. Eligibility for pupil premium/free school meals was used as an indicator of individual-level disadvantage (Gorard et al., 2019).

3.4.2 Diary, interview and interview alternative

The data from the diaries, interview and interview alternative included photo diary entries plus accompanying text, photos of written diary entries, transcripts of audio diary entries, interview transcripts and photos of completed home activity sheets. Thematic analysis was conducted (Braun & Clarke, 2006) with the aid of thematic networks (Attride-Stirling, 2001) to organise the data, facilitate rich descriptions, and allow for unanticipated insights. Following familiarisation with the data through transcription and repeated active reading (Braun & Clarke, 2006), an initial coding framework was devised, starting with theory-driven codes (DeCuir-Gunby et al., 2010), for example, the dimensions of science capital (Archer et al., 2015; Godec et al., 2017), and codes directly related to the research questions (Appendix I). Using NVivo 1.4, the data was dissected according to these codes and new data-driven codes were generated where these seemed pertinent to the research questions ('school science') or revealed unanticipated information ('potential value of participating in the research'). The flexibility of this method was advantageous for the exploratory element of this study, allowing the analysis to be guided by theory and also responsive to the data. Next, themes within the collections of coded segments were identified (Attride-Stirling, 2001) and individual thematic maps were generated to more easily interrogate the relationships between themes (Braun

& Clarke, 2006). A review was then conducted at the level of the theme and the dataset as a whole to assess whether they form a coherent message and satisfactorily reflect the data. The final coding framework is presented in Appendix J.

A thematic network was constructed to summarise the main themes from the diaries, interviews and interview alternative across all cases (see Figure 1; Attride-Stirling, 2001). Similar basic themes were clustered within three higher-level organising themes, which reflected research questions 1–3. The coded segments of data were reviewed to verify that the network reflected the data and the data supported the network. This thematic network facilitated a global analysis of themes, while NVivo facilitated the analysis of individual cases and specific cross-case comparisons.

3.5 Ethical considerations

Ethical approval was obtained from the University of Oxford Central University Research Ethics Committee (Appendix K), confirming that the ethical guidelines provided by the university and the British Educational Research Association were adhered to (BERA, 2018). For the safeguarding of children, the researcher obtained an enhanced Disclosure and Barring Service check.

Official consent to participate was sought from guardians and children through an online consent form (Appendix L). Information about participating was provided in text and video format to facilitate accessibility and that consent was as fully informed as possible. I support the 'ethics-as-process' approach, whereby consent is regularly and collaboratively re-assessed by the researcher and participants (Miller & Bell, 2012). At every new stage of the research, participants were asked to re-confirm their consent and reminded of their right to withdraw. After the interview, participants were asked if they were still happy for what they had said to be analysed and reported by the researcher. This was an attempt to acknowledge the limits of informed consent before the research takes place; neither the researcher nor the participant can fully anticipate what will be shared, therefore, it was considered ethical to re-assess consent at the end of data collection (Miller & Bell, 2012). The difference in power afforded to the researcher, guardians, and children has implications for informed consent and how freely children participate (Morrow, 2008). Therefore, encouraging children to take the lead was balanced with involving guardians as gatekeepers and sources of support (Dockett et al., 2012). For example, during the interview it was requested that an adult was present in the same room as children but their level of involvement was decided by participants.

Considering confidentiality, anonymity, and data protection, the importance of developing a relationship with participants in qualitative research makes absolute anonymity difficult, therefore, researchers have an obligation to assure confidentiality (Goddard & Mudaly, 2009). All data was stored securely on the university-provided platform OneDrive on a password-protected computer or

on a password-protected research phone (only for WhatsApp communication). All children and guardians were allocated a pseudonym that was used for data storage and reporting. A key to pseudonyms, and other identifying information were password-protected. Similarly, audio recordings were password-protected and deleted following transcription. For the diaries, explicit consent was sought for audio recordings and photographs of children, and children were asked to obtain verbal consent before taking photographs of adults only. Participants were informed that no photographs of people would be included in the final report. Prioritising the safeguarding of children, it was requested that guardians were responsible for sending diary entries. Specific channels of communication were established at the beginning of the research to prevent the collection of data from ambiguous or untrustworthy sources.

3.6 Summary

This chapter has presented the rationale for a case study research design guided by a critical-constructivist, child-led approach that employed a questionnaire, diaries, and interviews. Thematic network analysis was chosen to interpret children's reports of science in their lives alongside quantitative indicators of sociodemographic information and children's science capital, identity, and aspirations. The findings resulting from this research design are presented and discussed in the following chapters.

CHAPTER FOUR: FINDINGS

This chapter presents the results of an analysis of the data received from questionnaires, diaries, and interviews (including the alternative format). The findings are organised to directly address each of the research questions and include a global thematic network crafted from interview and diary data, as well as case summaries and cross-case comparisons to present the identified themes in the context of the questionnaire data.

4.1 Research question 1: What events do children report as being science-related in their everyday lives?

The first research question aimed to understand what experiences children see as being science-related in their everyday lives. In their diaries and interviews, the four children in this study presented a wide range of events, which were grouped into two themes shown in Table 2. The first theme drew on the science-related behaviours and practices recognised by Archer et al. (2015) and the 2019 survey of public attitudes to science (Department for Business, Energy and Industrial Strategy, 2020) to identify a narrow definition of science-related event as: a traditionally science-related event or experience, such as going to science museums or science clubs, doing experiments or using science kits at home; fixing or building things at home; going on nature walks; and/or programming computers. Any events that children saw as science-related but that did not satisfactorily fall into the narrow definition were grouped into the second theme, a broad definition of science-related event. This second theme was considered to be child-led as it has been developed from the responses children gave in this study in contrast to the narrow definition, which has been driven by the field of science.

4.1.1 Narrow definition (field-led)

All children reported at least one event that was considered to fall under the narrow definition of science-related. Ava reported the most events in this category, but they varied from doing weekly science experiments to playing with clay. Several of the events in this category could be argued to fall under either the narrow or broad category, particularly those that were not explored further in an interview. For example, a book of experiments is explicitly framed by science whereas building a den may be considered to require an explanation as to why it is science-related. Consequently, it is important to acknowledge my influence as the researcher in deciding which events align with each definition. Ethan, Josh, and Ollie reported relatively more traditional events, including building an electrical circuit and watching a science demonstration. Overall, it was notable that despite all

children being classed as having medium or high science capital, the number of science-related events falling under the narrow definition was markedly less than those falling under the broad definition.

Table 2 | Events that children reported as science-related in the diaries and interviews

Narrow definition (field-led)	Broad definition (child-led)	
Building or making things** • Compass • Floating pencil • Salvaging a pallet to make a chair • Electrical circuits • Railway controller • A ramp to test which train was best at going downhill • A den from lots of different materials • Jumping clay • Lego models Science club Science demonstration Weekly science experiments	Playing games* • Aerobie • Running • Nerf guns • Rummikub Playing at the playpark on the roundabout Watching a film or TV* Taking care of pets or animals* • Cleaning fish tank • Turning light on/saying hello to fish • Pet food Writing and drawing** Making tea/using kettle Breakfast Eating lunch Dinner Cooking • 'Ugly Pudding' • BBQ • Pancakes Coffee machine Fireworks Sparklers	Lift Art Art club PE Exercise Sports club Walking Learning a new topic Learning at church Brushing teeth with electric toothbrush Admiring/growing plants in a propagator Piano Power cut Running a bath Electric train lines/rails Washing machine Nose spray Dogs Pets De-icing the car Car wheels

Note: *, prompt in interview (Ava, Ethan, Josh); **, prompt in pilot interview only (Josh). However, many of the specific examples were given independently.

4.1.2 Broad definition (child-led)

All children reported multiple events that were considered to fall outside the narrow definition of science-related, and so were included under the broad definition. All children reported some form of playing and cooking/food as being science-related, although each gave different specific events. However, beyond those commonalities and the interview prompts, children reported a range of different events. The number and breadth suggest that all the children regularly recognise science in

their everyday lives and this was affirmed by one child who said "[I] kind of see everything's related to science". None of the children explicitly mentioned school-related science when reporting events.

4.2 Research question 2: How do children explain why they see an event as science-related?

The second research question aimed to explore reasons children gave as to why events were science-related. Three out of the four children provided explanations, either unprompted in the diary or following prompts in the interview, which have been grouped into five themes.

4.2.1 How things work

The most common clarification for why something was related to science involved descriptions of, or enquiry into, how things work. For example:

> "Going to the park and playing on the roundabout was related to science because when I give the roundabout a push and jump on it, it keeps going for a bit as the power in the push I made gets used up by friction."

Ava and Ethan primarily discussed this from an outward-looking perspective that considered how things around them work. For example, how trains and lifts are powered by electricity, and how the picture on the TV is made of pixels. Josh also provided many explanations from an inward-looking perspective that considered how he works. For example, "how I am learning" and "my heartbeat increased". This was reflected by one child when discussing the interview prompts that "for all of these things you need […] to use brain science" and that games involving running use muscles, bones, and tendons to move your legs.

4.2.2 Components of science

This theme involved children explaining an event as science-related by linking it to keywords or topics indicative of traditional science but not including further explanation. For example, playing games was considered to be related to science "because you use energy and energy is science". Other explanations connected events to nature, electricity, and the internet. Gonsalves et al. (2013, p. 1082) refer to a similar theme as 'scientific placeholders', whereby teenage girls identified resources to show what science means to them, but without context and typically "accompanied with an affirmation rather than explication of their relationship to science". It may be that the events were framed by school science, as in the work by Gonsalves et al. (2013), but this was not explicitly reported by children. The few times that school science was brought into the discussion were instigated by a guardian and, consequently, have not been included in the findings.

4.2.3 Learning

Another theme for categorising events as science-related involved learning and primarily involved learning by doing. Indeed, when asked by his guardian how he prefers to find something out, one child replied “by doing it, because it’s more fun to do that”. One event bridged several themes: making pancakes was explained to be science-related because it involves “natural things made into other things and change state”, which highlights a consideration of how things work and components of science. When asked in the interview how they had learned about changing states, they replied “well I see it happen because we make pancakes [and] we pour the liquid in and then it goes and then I see it happen”, suggesting that this event involves learning about how things work in an everyday context. In general, events grouped under this theme involved finding things out, including building a ramp to test which train was best at going downhill, where the pieces go in a Lego model, and learning to write new words.

4.2.4 Invention

This theme encompasses events that were described as science-related because they were made possible by science. For example, “I brushed my teeth with an electric toothbrush which was invented by science” and “playing with clay was related to science because someone did a scientific experiment to create jumping clay”. This reasoning was not provided for many events but was given for both unprompted events reported in the diary and in response to the interview prompt ‘watching a film or TV’.

4.2.5 Being

This theme involves explanations that relate to personal qualities. Building a Lego model was described as science-related “because you have to have intelligence” to find out where the pieces go, and painting because it involves being tidy: “you have to make sure it’s not messy”. This aligns with dominant perceptions of science that associate it with cleverness and, more broadly, with behaviours that are connected with being good at school (Archer et al., 2020; Tintori & Palomba, 2017; Varelas et al., 2011).

4.3 Research question 3: How do children explain why they see themselves or others as a science person?

The third research question wanted to explore reasons why children saw themselves or others as science people. In the questionnaire and/or interview, all four children identified themselves or at least one person in their life as a science person. Three out of the four children were asked in the

interview to explain the reasons why or when they feel like a science person. Their responses have been grouped into four themes.

4.3.1 Engage in science-related interests

The most common explanations for someone being a science person involved engaging in, expressing a desire to engage in, and/or enjoying engaging in interests or activities that children defined as science-related, such as sport (because it uses energy), and art. The latter was not limited to traditionally scientific art, but involved creating a model out of Lego and using that as a basis for drawings. Another child described himself as a science person because he likes maths, how things work, and seeing how things are powered. Notably, this enjoyment of maths occurred outside of school as he reported "I don't really like math in school but I do like maths". Another child reported feeling like a science person when they do regular science experiments using a book of experiments, but not like a science person when they do not do any after-school science clubs. In addition, engaging in related interests was not limited to describing science people, one child reported that they know history and arts people and explained that this perception was based on "just what you're into, what you're interested in".

This theme also includes some critical reflection on internal motivation, accessibility, and inclusion by one of the children. When asked whether going to science centres or museums was important for being a science person, they made the distinction that "wanting to go or enjoying going is more important than actually going" and that "you could be a science-y person but just not be able to go to a science museum or a science centre. You don't have the access, you don't have the money". The importance of accessibility included access to people, as talking about science was not considered important for being a science person because "you might not have people that like science in your life. It might be you're the only one who likes science and all your friends don't like science". This was echoed by another child: "because when you talk about science to other people they sometimes can just ignore you and carry on with their conversation. Or just not bother about science and carry on with what they're doing".

Reading about science was also not considered important for being a science person: "I don't really read about science. I think you could, but you don't need to read about science. Some people just don't like reading". Similarly, for science clubs: "some people just aren't into clubs, some people don't like getting told what to do […] and they might love science but not really go to a club". This reasoning could also help to explain the potential conflict where Ava reported that not doing science clubs made her feel not like a science person, but also reported that clubs do not really matter for being a science person. Perhaps this shows that Ava considered clubs important for her

personal science identity, but not for people in general. It seems that certain activities have the potential to be important for being a science person, but they do not *have* to be and should not exclude someone from seeing themselves or being seen as science person.

4.3.2 Talk with people who are interested in science

Despite two of the children responding that talking about science in general is not important or does not really matter for being a science person, a more specific theme was identified that suggests that talking with people who are interested in science is important. When discussing why science clubs were important, one child compared them with science centres and museums and highlighted that you are more likely to know and talk with the other people there. They also considered a grandparent to be a science person "because she normally asks me a few questions and there's a few words that she taught me that I like, like cascade", suggesting that it is their discussions, perhaps focused on science-related things as 'cascade' was a word used in their diary, that led them to associate this person with science.

4.3.3 Find things out

Another association that children made with science people was that they find things out. For example, one explanation for considering that going to science centres and science museums is important for being a science person was because "you find new things out and finding new things is important". In addition, one child who saw themselves and two family members as science people discussed how they ask and answer questions and learn new words together. A child's science teacher "who teaches lots of science and is interesting and interested" was also identified as a science person. Similarly, one child thought that their science teacher saw them as a science person because "I keep on putting my hand up", suggesting that a desire to find things out and/or be able to answer questions is also important.

4.3.4 Have a science-related job

More than one child reported science teachers as being science people, with one child having several family members in this role. The explanations for why they were seen as science people are encompassed in the previous themes: they engage in science-related interests and ask questions. However, this would be interesting to explore further considering that, one child's parents used to work in a science museum, but this was not a reason that was given for seeing them as science people.

4.4 Thematic network

The themes identified above to address the first three research questions were organised into a thematic network shown in Figure 1. As discussed, the science-related events reported by children were grouped into those that were considered to fall within or outside a narrow definition of science-related. In the thematic network, this was extended beyond the context of the research study to hypothesise that children's science-related experiences in everyday life can be grouped into the same categories, and that this grouping is informed by what children see as science and how they, or others that they consider science people, engage in science-related activities and interests.

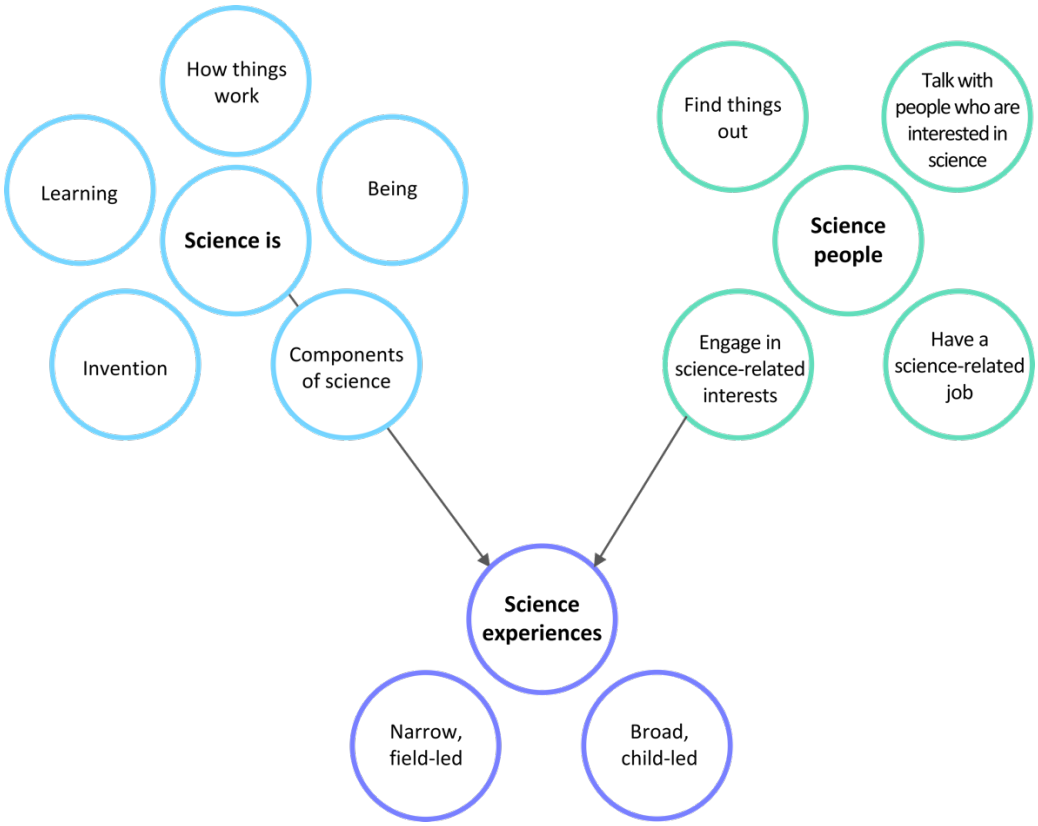


Figure 1 | Global thematic network showing the themes identified from diaries and interviews about what events and who children see as science-related, and why

4.5 Research question 4: How do children's responses vary by children's science capital index score, gender, ethnicity, and indicators of socioeconomic status?

This section adds to the previous sections by incorporating children's questionnaire responses to summarise all the data for each participant, including science capital index quantile, gender, ethnicity, and indicators of socioeconomic status. Comparisons are then made across cases to address how children's responses vary according to their score on the science capital index and factors that are reported to be linked to that score. For a succinct summary of the demographic information, science capital index quantile, and sources of data collected for each of the

participants, please refer back to Table 1. Figure 2 shows the responses of the three children that completed the questionnaire to items exploring science identity, science aspirations, and groups of science people in their lives. Figure 3 shows individual thematic maps that demonstrate which themes of the thematic network were evidenced by each participant.



Figure 2 | Children's responses to questionnaire items exploring science identity, science aspirations, and groups of science people in their lives

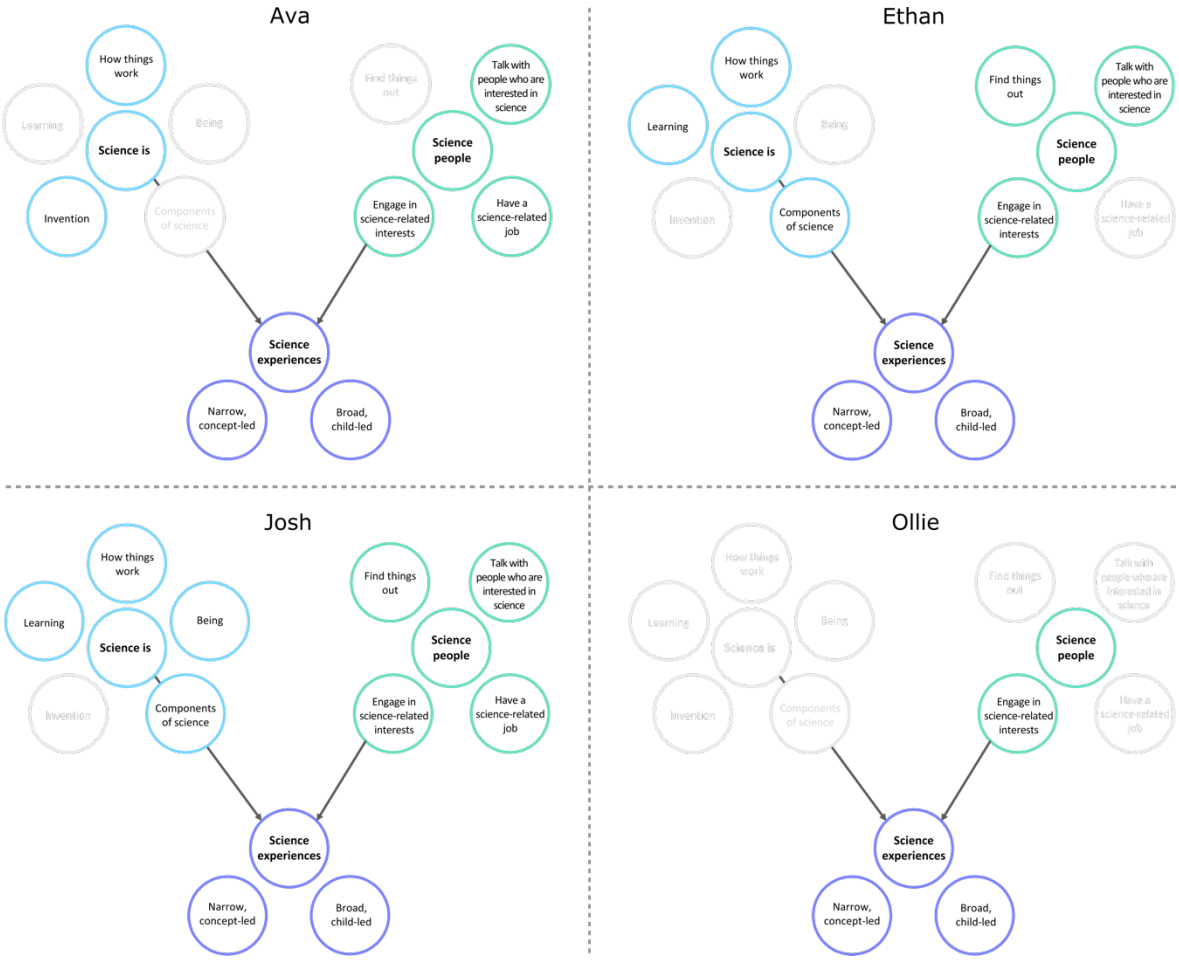


Figure 3 | Individual thematic maps for each participant

4.5.1 Case summaries

This section provides a summary of all the data for each of the four participants. Ava completed the questionnaire, two days of written diaries, and the interview alternative. She self-reported as female and 8 years old, and her guardian reported her as not eligible for free school meals/pupil premium, her ethnicity as White British, and her postcode was identified as one in the 30% least deprived neighbourhoods in England. Her answers to the science capital index items classified her as having medium science capital.

Ava's responses to questionnaire items suggest a neutral-negative science identity, despite expressing positive science aspirations and agreeing that anyone can become a scientist. She reported one person in her community that she would describe as a science person, which her diary suggests is her science teacher. Her neutral opinion of herself as a science person but positive aspirations could possibly be connected to how Ava explained events to be science-related. The science events she reported were primarily discussed in the context of objects, doing, how things

work, and invention. Her reports did not include the themes of learning and being, perhaps suggesting an externalised (but still broad) appreciation of and engagement in science that is not strongly connected to her perception of herself. The theme of invention, that an event is related to science because it was made possible by science/a scientist, combined with positive aspirations and science capital could suggest that Ava respects, or possibly even reveres, the field. This could be connected to her science identity as it has been shown that science and scientists are associated with cleverness and masculinity, therefore, not seeing herself as a science person and not agreeing that people like her work in science could be a reflection of not feeling clever enough or not feeling like she would fit in.

However, an alternative interpretation is that Ava respects science and has positive science aspirations *in spite of* not strongly feeling like a science person. She may recognise that attributes that are traditionally associated with science people do not strongly align with her identity but does not allow that to stop her aspiring to be part of a field that she admires. Indeed, expressing that her science teacher is her favourite may allude to the impact of a positive, female role model in science. Another alternative understanding challenges research that indicates that science identity is associated with science aspirations (Black & Hernandez-Martinez, 2016): it simply may not be that important for Ava to feel like a science person to want a job that uses science. It may be that asking if individuals see themselves as science people encourages them to deny other parts of themselves or build up their science self, when for some people their full identity may be an integration of multiple identities that contribute as a collective (Lorde, 1984). In this way, Ava's science self may be just one part of her full identity that contributes to her science aspirations.

In addition, As Avraamidou (2020) highlights it is crucial to apply an intersectional lens to science identity and participation, therefore, it is important to acknowledge that being White British and of high socioeconomic status affords Ava privilege disproportionately to children of marginalised ethnicities and lower socioeconomic status, which may enable science aspirations without feeling strongly like a science person. For instance, Ava agreed that anyone can become a scientist, however, it has been shown that for non-dominant groups, science is less likely to be considered something that is conceivable (Archer, DeWitt, & Wong, 2014) and having a recognised science identity facilitates seeing themselves in science in the future (Calabrese Barton et al., 2013).

Josh completed the questionnaire, seven days of diaries, and the interview. He self-reported as male, was 8 years old, his guardian reported him as not eligible for free school meals/pupil premium, his ethnicity as White British, and his postcode was identified as one in the 40% least deprived neighbourhoods in England. His answers to the science capital index items classified him as having high science capital.

Josh's responses to the questionnaire suggest a positive science identity and strongly positive science aspirations, which are perhaps influenced by seeing lots of his family members and a friend/neighbour as science people. This is supported by research that suggests that, particularly for children with a high socioeconomic status, family science capital can facilitate seeing a future in science as a more realistic possibility than for those who are less privileged (Archer et al., 2012). Although he strongly agreed that anyone can become a scientist, he neither agreed or disagreed that people like him work in science. Almost all of the themes identified in the thematic network were evidenced in Josh's diaries and interview, perhaps reflecting his slightly higher score on the science capital index. He was the only participant to associate science events with 'being', which may suggest a more internalised engagement with science. He also gave the most detailed discussion of why he saw himself as a science person, which included a range of science-related activities that he likes to engage in as well as the importance of being recognised by others. Indeed, recognition has been argued to be a core dimension of science identity and significant predictor of choosing a career in science (Avraamidou, 2020).

It was notable at first that Josh neither agreed or disagreed that people like him work in science, particularly as research suggests that science is associated with white, male, and middle-class characteristics (Tan & Barton, 2010). However, this highlighted a potential difference in comprehension of the question. To the researcher, Josh's high science capital and identification of lots of people in his life that are science people suggest that he would be more likely to consider that people with attributes similar to him are currently working in science. However, in the interview Josh highlighted multiple times how he considers that he thinks differently about science to his friends and they are not very interested in science. This suggests that Josh might understand the question as asking whether he sees people like him, for example his friends, working in science in the future. This supports the notion that broadening what counts and who is valued in science among the most under-served is likely to benefit many children. Working to build the science capital of Josh's friends would hopefully encourage them to feel like science is more accessible, which may have a knock-on effect of Josh being more likely to feel that people like him work in science due to being able to share his interest in science with his friends.

Ollie completed the questionnaire and four days of audio diaries. He self-reported as male and 10 years old, and his guardian reported him as not eligible for free school meals/pupil premium, his ethnicity as White, and his postcode was identified as one in the 30% least deprived neighbourhoods in England. His answers to the science capital index items classified him as having medium science capital. In response to the questionnaire, Ollie demonstrated mixed science identity and aspirations. He agreed that he saw himself as a science person and strongly agreed that anyone

can become a scientist, but disagreed that people who are like him work in science. He reported that he did not know whether he would like to become a scientist, but strongly agreed that he would like a job that uses science. He also reported that he would describe at least one of his parents or guardians as a science person. Ollie did not provide explanations as to why the events in his diary were science-related and did not take part in an interview so this and what he associated with being a science person were not able to be explored. That Ollie sees himself as a science person and that anyone can become a scientist suggests that he does not see science or the perception of a scientist as exclusionary. This then leads to the question that if anyone can become a scientist, what does Ollie believe to be the reasons why people like him do not work in science? The difference between Ollie wanting a job that uses science and not being sure whether he wants to be a scientist could be a reflection of his science capital. Indeed, the range of events reported in his diary suggests that he may recognise the transferability of science to careers beyond a scientist. Alternatively, he may have a narrow perception of what is associated with being a scientist and feel that this does not encompass his interests.

Ethan completed one diary day consisting of photos accompanied by written descriptions, and the interview. He did not complete the questionnaire so his sociodemographic information, science capital quartile, and some responses to items exploring his science identity and science aspirations are unknown. His gender has been assumed from his guardian's use of he/him/his pronouns, but this was not explicitly reported by Ethan himself. In the interview Ethan reported seeing himself and his parents as science people.

The diaries and explanations of science-related events shared by Ethan mainly revolved around how things work and components of science, such as electricity, alongside some discussion related to learning, particularly in the context of doing an experiment to find something out. In slight contrast to his explanations of science-related events reflecting possibly more traditional experiences of science in his everyday life, his attitudes around science for other people promoted inclusivity. It would have been interesting to see whether Ethan agreed that anyone can become a scientist as he recognised potential barriers, for example, to visiting science centres, but also reported that none of the interview prompts were important for being a science person, suggesting that he does not believe there is a particular way to be a science person. Despite Ethan not independently talking about how his parents worked in a science museum, it may be that this has informed Ethan's views as informal science learning spaces typically aim to widen access to science (Archer et al., 2021).

4.5.2 Cross-case comparisons

First, considering science capital index score, comparisons are drawn between Josh with high science capital and Ava and Ollie with medium science capital. Compared to Josh who responded positively to almost all the questionnaire items, the most notable difference was that both Ava and Ollie reported having far fewer science people in their life. Ava and Ollie also expressed a slightly less positive science identity, and Ollie did not know if he aspired to be a scientist. Almost all the themes in the thematic network were identified in the data shared by Josh, whereas fewer themes were identified with Ava and Ollie. The science events reported by Josh also seemed to cover a greater breadth of everyday life. However, this could be because Ollie did not take part in an interview, Ava took part in the offline interview alternative, and Josh was asked to complete a diary for seven days for the pilot study so there was more data associated with Josh.

Second, to consider gender, responses from Ava are compared with those from Josh, Ollie, and Ethan. There was very little difference between Ava, and Josh and Ollie in questionnaire responses. Ava reported the least positive science identity, however, she reported more positive aspirations than Ollie. As discussed above, the themes learning and being were not identified in the data shared by Ava, and she also did not discuss components of science or use scientific placeholders in the same way as Ethan and Josh. Both Ethan and Josh considered science-related events to involve learning and problem-solving, but this was discussed in the context of themselves, for example, solving the puzzle in a game. In contrast, Ava was the only child to report how others had used science to create things in her life, such as her electric toothbrush. Children's discussions of science people were generally similar, except that the theme that science people find things out was not evidenced by Ava. Combined with the lack of identification of the theme of learning among her science-related events, this could suggest that Ava focused on knowing rather learning and may support the hypothesis that she associates science and scientists with cleverness.

Finally, considering both ethnicity and socioeconomic status, the responses from Ava, Ollie, and Josh are discussed as a group as their ethnicity was reported as White and their socioeconomic status was classified as high. It was interesting that Ava, Josh and Ollie all agreed that anyone can become a scientist, but responded negatively or neutrally to whether people like them work in science. Perhaps it would not be surprising that individuals from dominant groups are likely to consider that anyone can become a scientist. Those with power or capital, such as white privilege or economic security, can move through life unaware of the extra barriers faced by individuals from non-dominant groups. As highlighted above, Ethan discussed some of these barriers, but it is unknown from what position he recognises these barriers, as an outsider with privilege or an insider who has possibly faced those barriers. This is not to place any responsibility on these children or to

suggest they should know better. It would be interesting to investigate further why children did not agree that people like them work in science. Considering Josh's discussion that his friends are not interested in science, could it be that none of the children have friends who they consider science people? It was notable that peers were rarely mentioned in children's diaries. Could it be that they are the only, or one of only a few, science people among their peers? Or could it perhaps be due to a lack of exposure to people in science careers? Careers education has been identified as under-serving students and is a target area for improvement by the UK government (Moote & Archer, 2018; The Committee of Public Accounts, 2018).

4.6 Summary

The diaries and interviews revealed that the children in this study each saw a broad range of events in their lives as science-related. Correspondingly, people were considered science people for engaging in those science-related activities, which were generally everyday rather than formal or informal science experiences. Themes could be identified among children's responses, but the specific data they each provided was mostly unique. However, similarities were perhaps masked by the lack of variability in children's science identity, aspirations, science capital index score, ethnicity and socioeconomic status. One particularly interesting commonality between participants was their agreement that anyone could become a scientist but people like them do not work in science. This is discussed further, along with other key findings, in the next chapter.

CHAPTER FIVE: DISCUSSION

This chapter reflects on key findings from this study and highlights where research with this younger age group supports and contrasts with existing literature. An evaluation of the research approach is discussed, particularly in relation to the philosophical approach of the research design. Opportunities for a more rigorous study design are identified and key reflections and recommendations for the field of STEM are presented.

5.1 Discussion of main findings

Building on the findings discussed in the previous chapter, this section aims to offer a broader discussion of salient topics that were identified as well as surprisingly absent from the data.

5.1.1 Children have a broad view of what and who is science-related in their everyday lives

The events recognised by children in this study as science-related were varied and individual, and included both narrowly and broadly science-related experiences. Correspondingly, the interests and activities that children saw as important for being a science person were also varied and individual. This suggests that the dimension of science capital that covers science-related practices and behaviours, and the corresponding items in the science capital index, are perhaps not broad enough (Archer et al., 2015). For example, consumption of science-related media, which was a key component of the dimension, was not commonly reported as a science-related event in this study. Similarly, reading about science was not strongly considered to be important for being a science person. In addition, the examples of out-of-school science learning outlined by Archer et al. (2015), such as visiting science centres and zoos, were seen as important for being a science person by some children but not others, and many more events were reported by children as being science-related than suggested by the authors' original conceptualisation of science capital. This supports later research by the science capital team that structured informal science experiences were not as strongly correlated with science aspirations as unstructured science-related activities, such as those that can take place at home (DeWitt et al., 2016).

Furthermore, the breadth of science-related events identified by children in this study supports recent research into equity in informal STEM education (ISE) that found that ISE was failing to recognise everyday science learning (Godec et al., 2021). The authors found that "many of the young people in our study had STEM interests and participated in a range of 'everyday' ISE (e.g. gaming, tutoring) [but] while these practices might reflect substantive funds of knowledge, they might not necessarily be leveraged by formal or even informal STEM learning settings" (Godec et al.,

2021, p. 20). The authors even highlight that survey methodology, such as the science capital index they developed which includes pre-defined science activities, risks overlooking the breadth of what young people engage in and reinforcing the value given to dominant practices, along with elitist views of 'correct' science engagement (Dawson, 2019; Godec et al., 2021). This highlights the importance of open-ended investigation when looking to understand young people's engagement with science.

It is also important to discuss how the breadth of what is seen as science-related and/or important for being a science person may be a reflection of the capital and privilege held by the children in this study. Godec et al. (2021) discuss 'omnivorous' consumption of ISE, whereby a range of 'highbrow' and 'lowbrow' (or traditional and non-traditional) practices are engaged in, as an elite way of participating in ISE (Peterson & Kern, 1996). Demographic information for children in this study suggest that they predominantly have high socioeconomic status and the interviews and communication with their guardians suggest they likely also have high family (science) capital and so are more likely to aspire to a career in science and to feel like a science person (Archer et al., 2020; DeWitt, Archer, et al., 2013). This may be facilitated by omnivorous consumption of science education, as exemplified in children's diaries and interviews. In the work by Godec et al. (2021), the profile of 'served cultural omnivores', who regularly engage in broad (science-related) cultural activities but do not necessarily have strong science aspirations, largely matched the children in this research in that they were disproportionately likely to be white, have high cultural capital (a signifier of high socioeconomic status), and medium science capital scores. This highlights how informal science education can be seen to be partly serving more privileged groups, yet still not recognise the value of science in their everyday lives, let alone in the lives of more minoritised groups.

This is not to suggest that less privileged children do not have a broad recognition of science in their lives, rather that children's expertise and habitus will be different and make it easier or harder for them to have, or want to have, an omnivorous approach to science education. Dawson (2019) highlights that for some groups, not only is an interest in science not enough to make science learning and careers conceivable and/or accessible, but the field of science may not even be desirable as it "has a socio-political history [and] is marked by colonialism, racism, misogyny, ableism, homophobia and heteronormativity and other forms of oppression" (p. 29). Consequently, a science capital-inspired teaching approach for primary-level education, similar to the one developed for secondary education (Godec et al., 2017), has great potential to engage children, at least in formal education, following the recommendation of Wallace (2018) to assume that individuals are always-already scientific. These teaching methods encompass an asset-based approach by aiming to broaden what counts as science through valuing students' experiences,

interests and identities (Godec et al., 2017). Importantly, the focus is on changing the field to value young people, rather than changing young people to be valued by the field.

5.1.2 School science

Considering that research and policy decisions often concern the role that formal education can play in encouraging young people to take up STEM careers and in transforming STEM to be more equitable (Godec et al., 2017; The Committee of Public Accounts, 2018), it seemed pertinent to discuss the surprising lack of data from children in this study linked to school science. This absence supports the suggestion that there is a disconnect between science in everyday lives and school science, particularly that canonical science and that which is taught at school is not directly meaningful for everyday life (Aikenhead, 2003; Gonsalves et al., 2013) and "leaves little room to celebrate and productively leverage different kinds of students' science-related interests and identity work" (Carlone et al., 2014, p. 863). Moreover, Upadhyay (2006) highlights that this disconnect is particularly significant for children in urban schools, who are disproportionately more likely to be of minoritised ethnicities and low socioeconomic status.

In contrast to Gonsalves et al. (2013), who found that canonical ideas about science, typically from school science, were pervasive and unable to be disrupted in an out-of-school club, this study suggests that everyday non-formal science engagement may be prominent in children's lives. Children's foregrounding of out-of-school experiences as science-related could be connected to the diary methodology, which was completed outside of the school day, or to the disrupted school year due to COVID-19. Nonetheless, both the diary and interview were deliberately open to try and allow for any elements of children's lives to be captured depending on what they wanted to highlight, suggesting that perhaps school science was not as dominant in these children's lives. However, this could be another way that privilege can play out in terms of science capital. In their research with low-income African American children, Varelas et al. (2011) found that doing science was intertwined for some children with doing school, whereby children expressed being like a scientist when exhibiting 'good' school behaviours, such as listening and getting good grades. The authors discuss that such a relationship with science "may mean that [children] had constructed the view that unless they behaved well they would not have access to science, and would be invisible, outsiders, and left out" and go on to say that "invisibility, marginalization, and exclusion are experiences that students of color (mostly older ones) bring up as part of their racialized experiences with science" (Varelas et al., 2011, p. 846). Consequently, the children in this study may feel less pressure to connect with science, which enables them to focus on the science in their everyday life.

5.1.3 Anyone can become a scientist but people like me do not work in science

It was interesting that despite their medium and high science capital scores and broad recognition of science in their lives, none of the three children that completed the questionnaire agreed that people like them work in science. This could perhaps suggest that while they recognise science in their everyday lives, they do not perceive science to mutually recognise them. This would support that "there is often little overlap between students' perceptions of scientists and their images of themselves" (DeWitt et al., 2013, p. 1456) and findings by Padwick et al. (2016) that the attributes that young children associate with themselves, particularly those identified as not having high science capital, do not closely align with the attributes they associate with scientists. However, all three children in this study agreed that anyone can become a scientist. This suggests that a discourse similar to the myth of meritocracy may exist, in that in general children may believe that the institution of science is meritocratic and objectively accessible to all but they struggle to apply that belief to themselves personally. This conflict is reminiscent of research by Owens & de St Croix (2020) investigating schools as 'engines of social mobility'. The authors similarly found that students expressed seemingly contradictory beliefs; while many endorsed meritocratic narratives, all students questioned whether schools could help overcome the structural barriers that many students are challenged with. In agreement with Owens & de St Croix (2020), although encouraging students to believe that anyone can become a scientist is hopefully inspiring, it is a dangerous narrative to leave unchallenged as it runs the risk that when children do not believe that people like them work in science, they will see themselves as having failed to fit in or succeed (Bird & Rhoton, 2021).

5.2 Evaluation of the research approach

A significant limitation of this research was the difficulty in recruiting participants, and lack of inclusion of children with different science capital scores and demographic and socioeconomic backgrounds. Efforts were made to capture experiences from a wider range of children through asking a purposive sample of schools that had similar or higher numbers of pupils eligible for free school meals or pupil premium than the national average to ask children with different levels of science interest to complete an offline activity sheet. However, teachers reported not having enough capacity to take on this task due to restrictions resulting from the COVID-19 pandemic. This study highlights how the pandemic provided additional barriers to participation, which were likely exacerbated for disadvantaged groups. There was restricted access to schools; in general the population reported negative effects of the pandemic on their wellbeing, which likely affected capacity and willingness to participate (Gayer et al., 2020; Sevilla et al., 2020); and the research was conducted largely online so families may have been impacted by inequitable access to digital

resources (Foss et al., 2013). This study has taught me to thoroughly consider barriers to participation and to reflect on how structural inequities can play out in all stages of research. Being able to report only the experiences of children from more privileged backgrounds impacts the quality of the study, particularly from a critical research perspective, as this cannot be said to fully erode ignorance and misapprehensions and may not be considered enough to stimulate action to transform the current systems (Lincoln et al., 2018).

To assess the quality of qualitative research involving case study methodology, it is recommended to consider trustworthiness (Lincoln & Guba, 1986; Yin, 1994). The following strategies were used to develop credibility: triangulation of all data from multiple sources, which facilitated multiple engagements with participants and exploration of salient data through the interviews; regular debriefing with my supervisor for accountability and testing of hypotheses; and searching for rival explanations, particularly during thematic analysis (Cohen et al., 2018; Nowell et al., 2017). A critical-constructivist approach combined with case study methodology involving diaries and interviews provided detailed and strongly contextualised narratives of the data to facilitate transferability. Aiming for dependability and confirmability, I have tried to describe in detail the coding and analysis process alongside codebooks and examples of coded data (Appendix I and J), which were also provided to my supervisor to facilitate independent coding and corroboration (Nowell et al., 2017). I have also tried to be reflexive throughout the study and this report about my own positionality.

As discussed in the Introduction, I am a proponent of participatory research and in the future I would like to use this methodology to try to overcome some of the barriers to participation, to work collaboratively with children and families from under-served communities as researchers, and to offer more in return for participating, for instance, by integrating capacity-building into the research to support the conducting of the investigation, but also to support collective community action, if desired (Cahill, 2004; Groundwater-Smith et al., 2015). This would boost the quality and authenticity of the outcomes of the research from both a critical and constructivist research perspective, by foregrounding stakeholders' and participants' views, facilitating consciousness-raising, and equipping participants to make positive social change (Lincoln et al., 2018). I would also like to take a participatory approach to reporting the findings, inspired by Lundy et al. (2011), by inviting children to co-design a dissemination strategy aimed at their peers and science educators.

5.3 Implications

Considering the broader implications of the findings of this study in the context of equitable STEM learning research and practice, I present key reflections and recommendations for the field of STEM education:

1. The conflict between children not perceiving that people like them work in science and the breadth of science-related experiences that they reported suggests that the institution of STEM would benefit from a "re-figuring of science as an every-day experience" (Gonsalves et al., 2013, p. 1091). Broadening what counts as science by educational gatekeepers could see more children feeling like science represents a space where they fit in, which may have a knock-on effect on their peers seeing science as inclusive and desirable. As a result, this could positively impact the STEM pipeline as the more children connect their identity to science learning contexts, the more likely they are to participate in that context (Gonsalves et al., 2021).
2. In agreement with Godec et al. (2021), this re-figuring of science should be directed at changing the field of science education, that is systems, institutions, and practices, rather than young people. For example, Black & Hernandez-Martinez (2016) argue for a critical pedagogy whereby knowledge and learning that values individuals and is productive for the community has exchange value and is afforded symbolic capital, be that through a form of formal recognition or, as the authors suggest, through schemes such as education support grants. Moreover, the field must reflect on how a more equitable approach can be made durable, for example, Gonsalves et al. (2013, p. 1092) suggest that valuing the resources that children bring may not be enough if this takes places in the current educational systems, instead these resources need to inform transformation and "be seen as contributing to new and valid forms of engagement in science".
3. Correspondingly, the breadth of children's responses in this study strongly advocates for an asset-based approach, where educators and policymakers begin from the assumption that young people have valuable lived experiences, and it is the former's responsibility to leverage those experiences in the context of science education (Habig et al., 2021; Upadhyay, 2006). For example, Wilson-Lopez & Acosta-Feliz (2021) demonstrate that young people developed valuable knowledge and skills related to engineering through after-school and summer jobs, and advocate that educators recognise these experiences as epistemological resources.
4. It is important to be actively mindful of the current status quo and how science education and particular forms of science capital can serve to reproduce societal inequalities (Black &

Hernandez-Martinez, 2016; Wallace, 2018). For instance, alongside challenging dominant educational practices, Owens & de St Croix (2020, p. 403) recommend "encouraging greater critical discussion in schools [to] help students and staff to challenge meritocratic education discourse and to negotiate its expectations". Equipping individuals at all levels to examine who and what is being valued by science education can mobilise groups to pressure those with power to enact change. For this transformation to be successful, everyone involved, from young people and families to educators and policymakers, will need to be afforded time and training for critical reflection and reconstruction of their beliefs and practices (Upadhyay, 2006). Several tools have recently been developed and are in development, such as the science capital teaching approach already mentioned (Godec et al., 2017) and the youth equity compass, which supports the design and implementation of informal science learning practices in a socially just way (YESTEM Project UK Team, 2020).

5.4 Conclusion

Working within both formal and informal STEM education in England, the need, desire and resources to facilitate a more equitable landscape are evident. What is less clear is how to successfully and sustainably direct these resources to harness the experiences of children to create a world in which STEM literacy and STEM careers are desirable and conceivable. The concept of science capital is beginning to assist educators and policymakers in the contexts of secondary education and informal science learning, but there is currently a gap in the context of primary education. This study aimed to explore and inform a concept of primary science capital with 8–10 years olds using case study methodology involving diaries, interviews and questionnaires. The children in this study reported a broad range of events in their lives that they considered to be science-related and important for being a science person, challenging what was highlighted to be valued in the original conception of science capital, but supporting the more recently developed science capital teaching approach that aims to broaden what counts as science. Mention of school science was surprisingly absent, suggesting a disconnect between everyday science and canonical science. A disconnect was also found between children agreeing that anyone can become a scientist but disagreeing that people like them work in science. As a result, I argue for a re-figuring of the field of STEM to recognise its responsibility to investigate and value the science in children's everyday experiences and equip all involved to positively challenge the status quo going forward.

REFERENCES

Aikenhead, G. S. (2003). Review of research on humanistic perspectives in science curricula. *European Science Education Research Association Conference*. European Science Education Research Association Conference, Noordwijkerhout, The Netherlands. https://education.usask.ca/documents/profiles/aikenhead/ESERA_2.pdf

Alaszewski, A. (2006). *Using diaries for social research*. SAGE Publications Ltd. https://doi.org/10.4135/9780857020215

Angen, M. J. (2000). Evaluating interpretive inquiry: Reviewing the validity debate and opening the dialogue. *Qualitative Health Research*, *10*(3), 378–395. https://doi.org/10.1177/104973230001000308

APPG on Diversity and Inclusion in STEM. (2020). *Inquiry on equity in STEM education*. British Science Association. https://www.britishscienceassociation.org/inquiry-equity-in-stem-education

APPG on Diversity and Inclusion in STEM. (2021). *Inquiry into equity in the STEM workforce*. British Science Association. https://www.britishscienceassociation.org/inquiry-equity-in-the-stem-workforce

Archer, L. (2020, May 13). *Fun moments or consequential experiences? Thinking about STEM interventions through an equity lens [Video]*. https://www.raeng.org.uk/education/webinar-series/previous-webinars/fun-moments-or-consequential-experiences

Archer, L., Dawson, E., DeWitt, J., Godec, S., King, H., Mau, A., Nomikou, E., & Seakins, A. (2018). Using Bourdieu in practice? Urban secondary teachers' and students' experiences of a Bourdieusian-inspired pedagogical approach. *British Journal of Sociology of Education*, *39*(3), 283–298. https://doi.org/10.1080/01425692.2017.1335591

Archer, L., Dawson, E., DeWitt, J., Seakins, A., & Wong, B. (2015). "Science capital": A conceptual, methodological, and empirical argument for extending Bourdieusian notions of capital

beyond the arts. *Journal of Research in Science Teaching*, *52*(7), 922–948. https://doi.org/10.1002/tea.21227

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2012). Science aspirations, capital, and family habitus: How families shape children's engagement and identification with science. *American Educational Research Journal*, *49*(5), 881–908. https://doi.org/10.3102/0002831211433290

Archer, L., DeWitt, J., Osborne, J. F., Dillon, J. S., Wong, B., & Willis, B. (2013). *ASPIRES Report: Young people's science and career aspirations, age 10 –14*. King's College London.

Archer, L., DeWitt, J., & Willis, B. (2014). Adolescent boys' science aspirations: Masculinity, capital, and power. *Journal of Research in Science Teaching*, *51*(1), 1–30. https://doi.org/10.1002/tea.21122

Archer, L., DeWitt, J., & Wong, B. (2014). Spheres of influence: What shapes young people's aspirations at age 12/13 and what are the implications for education policy? *Journal of Education Policy*, *29*(1), 58–85. https://doi.org/10.1080/02680939.2013.790079

Archer, L., Godec, S., Calabrese Barton, A., Dawson, E., Mau, A., & Patel, U. (2021). Changing the field: A Bourdieusian analysis of educational practices that support equitable outcomes among minoritized youth on two informal science learning programs. *Science Education*, *105*(1), 166–203. https://doi.org/10.1002/sce.21602

Archer, L., Moote, J., Francis, B., DeWitt, J., & Yeomans, L. (2017). Stratifying science: A Bourdieusian analysis of student views and experiences of school selective practices in relation to 'Triple Science' at KS4 in England. *Research Papers in Education*, *32*(3), 296–315. https://doi.org/10.1080/02671522.2016.1219382

Archer, L., Moote, J., MacLeod, E., Francis, B., & DeWitt, J. (2020). *ASPIRES 2: Young people's science and career aspirations, age 10-19*. UCL Institute of Education.

Attride-Stirling, J. (2001). Thematic networks: An analytic tool for qualitative research. *Qualitative Research*, *1*(3), 385–405. https://doi.org/10.1177/146879410100100307

Avraamidou, L. (2013). Superheroes and supervillains: Reconstructing the mad-scientist stereotype in school science. *Research in Science & Technological Education*, *31*(1), 90–115. https://doi.org/10.1080/02635143.2012.761605

Avraamidou, L. (2020). Science identity as a landscape of becoming: Rethinking recognition and emotions through an intersectionality lens. *Cultural Studies of Science Education*, *15*(2), 323–345. https://doi.org/10.1007/s11422-019-09954-7

Bartlett, R., & Milligan, C. (2015). *What is diary method?* Bloomsbury Academic; Bloomsbury Collections. https://doi.org/10.5040/9781472572578

Barton, A. C. (1998). Teaching science with homeless children: Pedagogy, representation, and identity. *Journal of Research in Science Teaching*, *35*(4), 379–394. https://doi.org/10.1002/(SICI)1098-2736(199804)35:4<379::AID-TEA8>3.0.CO;2-N

BERA. (2018). *Ethical guidelines for educational research*. https://www.bera.ac.uk/researchers-resources/publications/ethicalguidelines-for-educational-research-2018

Bianchi, L., Whittaker, C., & Poole, A. (2021). *The 10 key issues with children's learning in primary science in England*. The University of Manchester; The Ogden Trust. https://seerih-innovations.org/just-good-stuff/10-key-issues

Bird, S. R., & Rhoton, L. A. (2021). Seeing isn't always believing: Gender, academic STEM, and women scientists' perceptions of career opportunities. *Gender & Society*, *35*(3), 422–448. https://doi.org/10.1177/08912432211008814

Black, L., & Hernandez-Martinez, P. (2016). Re-thinking science capital: The role of 'capital' and 'identity' in mediating students' engagement with mathematically demanding programmes at university. *Teaching Mathematics and Its Applications: An International Journal of the IMA*, *35*(3), 131–143. https://doi.org/10.1093/teamat/hrw016

Bourdieu, P. (1977). *Outline of a theory of practice*. Cambridge University Press.

Bourdieu, P. (1986). The forms of capital. In J. Richardson (Ed.), *Handbook of theory and research for the sociology of education* (pp. 241–258). Greenwood Press.

Bourdieu, P., & Passeron, J. C. (1990). *Reproduction in education, society and culture* (T. B. Bottomore, Ed.; R. Nice, Trans.; 2nd ed.). Sage.

Bourdieu, P., & Wacquant, L. J. D. (1992). *An invitation to reflexive sociology*. Polity.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Burke, C. (2018, June 19). *Bourdieu's thinking tools: Beyond the basics and beyond Bourdieu* [Audio podcast episode]. https://podcasts.apple.com/gb/podcast/srhe-society-for-research-into-higher-education-conference/id594177334?i=1000414343935

Cahill, C. (2004). Defying gravity? Raising consciousness through collective research. *Children's Geographies*, *2*(2), 273–286. https://doi.org/10.1080/14733280410001720557

Calabrese Barton, A., Kang, H., Tan, E., O'Neill, T. B., Bautista-Guerra, J., & Brecklin, C. (2013). Crafting a future in science: Tracing middle school girls' identity work over time and space. *American Educational Research Journal*, *50*(1), 37–75. https://doi.org/10.3102/0002831212458142

Carlone, H. B., Scott, C. M., & Lowder, C. (2014). Becoming (less) scientific: A longitudinal study of students' identity work from elementary to middle school science. *Journal of Research in Science Teaching*, *51*(7), 836–869. https://doi.org/10.1002/tea.21150

Cech, E. A., & Blair-Loy, M. (2010). Perceiving glass ceilings? Meritocratic versus structural explanations of gender inequality among women in science and technology. *Social Problems*, *57*(3), 371–397. https://doi.org/10.1525/sp.2010.57.3.371

Chua, M., & Adams, R. S. (2014). Using realtime transcription to do member-checking during interviews. *2014 IEEE Frontiers in Education Conference (FIE) Proceedings*, 1–3. https://doi.org/10.1109/FIE.2014.7044251

Clark, A. (2010). Young children as protagonists and the role of participatory, visual methods in engaging multiple perspectives. *American Journal of Community Psychology*, *46*(1–2), 115–123. https://doi.org/10.1007/s10464-010-9332-y

Claussen, S., & Osborne, J. (2013). Bourdieu's notion of cultural capital and its implications for the science curriculum. *Science Education*, *97*(1), 58–79. https://doi.org/10.1002/sce.21040

Cohen, L., Manion, L., & Morrison, K. (2018). *Research methods in education* (8th edn.). Routledge.

Creswell, J. W. (2013). *Qualitative inquiry & research design: Choosing among five approaches* (3rd ed.). SAGE Publications.

Dawson, E. (2019). *Equity, exclusion and everyday science learning: The experiences of minoritised groups*. Routledge.

DeCuir-Gunby, J. T., Marshall, P. L., & McCulloch, A. W. (2010). Developing and using a codebook for the analysis of interview data: An example from a professional development research project. *Field Methods*, *23*(2), 136–155. https://doi.org/10.1177/1525822X10388468

Department for Business, Energy and Industrial Strategy. (2020). *Public attitudes to science 2019* (BEIS Research Paper Number 2020/012). https://www.gov.uk/government/publications/public-attitudes-to-science-2019

Department for Education. (2013). *The national curriculum in England: Key stages 1 and 2 framework document*. https://www.gov.uk/government/publications/national-curriculum-in-england-primary-curriculum

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. https://doi.org/10.1080/09500693.2016.1248520

DeWitt, J., Archer, L., & Osborne, J. (2013). Nerdy, brainy and normal: Children's and parents' constructions of those who are highly engaged with science. *Research in Science Education*, *43*(4), 1455–1476. https://doi.org/10.1007/s11165-012-9315-0

DeWitt, J., Osborne, J., Archer, L., Dillon, J., Willis, B., & Wong, B. (2013). Young children's aspirations in science: The unequivocal, the uncertain and the unthinkable. *International Journal of Science Education*, *35*(6), 1037–1063. https://doi.org/10.1080/09500693.2011.608197

Dockett, S., Einarsdóttir, J., & Perry, B. (2012). Young children's decisions about research participation: Opting out. *International Journal of Early Years Education*, *20*(3), 244–256. https://doi.org/10.1080/09669760.2012.715405

Dockett, S., Einarsdottir, J., & Perry, B. (2017). Photo elicitation: Reflecting on multiple sites of meaning. *International Journal of Early Years Education*, *25*(3), 225–240. https://doi.org/10.1080/09669760.2017.1329713

Eder, D., & Fingerson, L. (2001). Interviewing children and adolescents. In J. F. Gubrium & J. A. Holstein (Eds.), *Handbook of interview research* (pp. 181–201). SAGE Publications, Inc. https://doi.org/10.4135/9781412973588

Finson, K. D. (2002). Drawing a scientist: What we do and do not know after fifty years of drawings. *School Science and Mathematics*, *102*(7), 335–345. https://doi.org/10.1111/j.1949-8594.2002.tb18217.x

Foss, E., Druin, A., & Guha, M. L. (2013). Recruiting and retaining young participants: Strategies from five years of field research. *Proceedings of the 12th International Conference on Interaction Design and Children*, 313–316. https://doi.org/10.1145/2485760.2485798

Gayer, C., Latham, R., Zerbi, C. E., Strang, L., Hall, V. M., Knowles, G., Marlow, S., Avendano, M., Manning, N., Das-Munshi, J., Fisher, H., Rose, D., Arseneault, L., Kienzler, H., Rose, N., Hatch, S., Woodhead, C., Morgan, C., & Wilkinson, B. (2020). *Impacts of social isolation among disadvantaged and vulnerable groups during public health crises*. ESRC Centre for Society & Mental Health, King's College London.

Goddard, C., & Mudaly, N. (2009). The ethics of involving children who have been abused in child abuse research. *The International Journal of Children's Rights*, *17*(2), 261–281. https://doi.org/10.1163/157181808X389920

Godec, S., Archer, L., & Dawson, E. (2021). Interested but not being served: Mapping young people's participation in informal STEM education through an equity lens. *Research Papers in Education*. https://doi.org/10.1080/02671522.2020.1849365

Godec, S., King, H., & Archer, L. (2017). *The science capital teaching approach: Engaging students with science, promoting social justice*. University College London.

Godec, S., King, H., Archer, L., Dawson, E., & Seakins, A. (2018). Examining student engagement with science through a Bourdieusian notion of field. *Science & Education*, *27*(5), 501–521. https://doi.org/10.1007/s11191-018-9988-5

Gonsalves, A., Cavalcante, A. S., Sprowls, E. D., & Iacono, H. (2021). "Anybody can do science if they're brave enough": Understanding the role of science capital in science majors' identity trajectories into and through postsecondary science. *Journal of Research in Science Teaching*, *2021*, 1–35. https://doi.org/10.1002/tea.21695

Gonsalves, A., Rahm, J., & Carvalho, A. (2013). "We could think of things that could be science": Girls' re-figuring of science in an out-of-school-time club. *Journal of Research in Science Teaching*, *50*(9), 1068–1097. https://doi.org/10.1002/tea.21105

Gorard, S., Boliver, V., Siddiqui, N., & Banerjee, P. (2019). Which are the most suitable contextual indicators for use in widening participation to HE? *Research Papers in Education*, *34*(1), 99–129. https://doi.org/10.1080/02671522.2017.1402083

Groundwater-Smith, S., Dockett, S., & Bottrell, D. (2015). *Participatory research with children and young people*. SAGE Publications Ltd. https://doi.org/10.4135/9781473910751

Guba, E., & Lincoln, Y. (1994). Competing paradigms in qualitative research. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (2nd ed., pp. 105–117). Sage.

Habig, B., Gupta, P., & Adams, J. D. (2021). Disrupting deficit narratives in informal science education: Applying community cultural wealth theory to youth learning and engagement. *Cultural Studies of Science Education*. https://doi.org/10.1007/s11422-020-10014-8

Hawkins, B. (2017, February 22). Developing our science engagement reflection tool. *Science Museum Group Blog*. https://learning.sciencemuseumgroup.org.uk/blog/science-engagement-reflection-tool/

Henry, M., Knight, J., Lingard, R., & Taylor, S. (1988). *Understanding schooling: An introductory sociology of Australian education*. Routledge.

Hill, M. (2006). Children's voices on ways of having a voice: Children's and young people's perspectives on methods used in research and consultation. *Childhood*, *13*(1), 69–89. https://doi.org/10.1177/0907568206059972

Hoskins, K., & Barker, B. (2020). The contemporary social mobility and equality policy context: Framing the problem. In *STEM, social mobility and equality: Avenues for widening access* (pp. 19–60). Springer International Publishing. https://doi.org/10.1007/978-3-030-49216-8_2

Hunleth, J. (2011). Beyond on or with: Questioning power dynamics and knowledge production in 'child-oriented' research methodology. *Childhood*, *18*(1), 81–93. https://doi.org/10.1177/0907568210371234

Jenkins, E. W., & Nelson, N. W. (2005). Important but not for me: Students' attitudes towards secondary school science in England. *Research in Science & Technological Education*, *23*(1), 41–57. https://doi.org/10.1080/02635140500068435

Jensen, E., & Wright, D. (2015). Critical response to Archer et al. (2015) 'science capital': A conceptual, methodological, and empirical argument for extending Bourdieusian notions of capital beyond the arts. *Science Education*, *99*(6), 1143–1146. https://doi.org/10.1002/sce.21208

Kahn, S. (2015). Another "M" for STEM? Moral considerations for advancing STEM literacy. *K-12 STEM Education*, *1*(4), 149–156.

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 and Society*, *18*(5), 329-343-329–343. https://doi.org/10.1002/CHI.807

Kirby-Green, E. (2017, November 28). Engaging young people with science: A science capital approach. *Royal Society of Biology Blog*. https://blog.rsb.org.uk/engaging-young-people-with-science-a-science-capital-approach/

Krosnick, J. A., & Presser, S. (2010). In P. V. Marsden & J. D. Wright (Eds.), *Handbook of survey research* (2nd ed.). Emerald.

Lardier, D. T., Herr, K. G., Barrios, V. R., Garcia-Reid, P., & Reid, R. J. (2019). Merit in meritocracy: Uncovering the myth of exceptionality and self-reliance through the voices of urban youth of color. *Education and Urban Society*, *51*(4), 474–500. https://doi.org/10.1177/0013124517727583

Lincoln, Y. S., & Guba, E. G. (1986). But is it rigorous? Trustworthiness and authenticity in naturalistic evaluation. *New Directions for Program Evaluation*, *1986*(30), 73–84. https://doi.org/10.1002/ev.1427

Lincoln, Y. S., Lynham, S. A., & Guba, E. G. (2018). Paradigmatic controversies, contradictions, and emerging confluences, revisited. In N. K. Denzin & Y. S. Lincoln (Eds.), *The SAGE handbook of qualitative research* (5th ed., pp. 108–150). Sage.

Lorde, A. (1984). Age, race, class and sex: Women redefining difference. In *Sister outsider: Essays and speeches* (pp. 114–123). Crossing 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. https://doi.org/10.1080/10409289.2011.596463

Mead, M., & Métraux, R. (1957). Image of the scientist among high-school students: A pilot study. *Science*, *126*(3270), 384–390. https://doi.org/10.1126/science.126.3270.384

Mejia, J. A., Revelo, R. A., Villanueva, I., & Mejia, J. (2018). Critical theoretical frameworks in engineering education: An anti-deficit and liberative approach. *Education Sciences*, *8*(4). https://doi.org/10.3390/educsci8040158

Merriam, S. B., & Tisdell, E. J. (2016). *Qualitative research: A guide to design and implementation* (4th ed.). Jossey-Bass.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook* (2nd ed.). Sage.

Miller, T., & Bell, L. (2012). Consenting to what? Issues of access, gate-keeping and 'informed' consent. In M. Mauthner, M. Birch, J. Jessop, & T. Miller (Eds.), *Ethics in Qualitative Research* (pp. 54–69). SAGE Publications Ltd. https://doi.org/10.4135/9781849209090.n3

Mills, C. (2008). Reproduction and transformation of inequalities in schooling: The transformative potential of the theoretical constructs of Bourdieu. *British Journal of Sociology of Education*, *29*(1), 79–89. https://doi.org/10.1080/01425690701737481

Moote, J., & Archer, L. (2018). Failing to deliver? Exploring the current status of career education provision in England. *Research Papers in Education*, *33*(2), 187–215. https://doi.org/10.1080/02671522.2016.1271005

Moote, J., Archer, L., DeWitt, J., & MacLeod, E. (2021). Who has high science capital? An exploration of emerging patterns of science capital among students aged 17/18 in England. *Research Papers in Education*, *36*(4), 402–422. https://doi.org/10.1080/02671522.2019.1678062

Morris, B. J., Owens, W., Ellenbogen, K., Erduran, S., & Dunlosky, J. (2019). Measuring informal STEM learning supports across contexts and time. *International Journal of STEM Education*, *6*(1), 40. https://doi.org/10.1186/s40594-019-0195-y

Morrow, V. (2008). Ethical dilemmas in research with children and young people about their social environments. *Children's Geographies*, *6*(1), 49–61. https://doi.org/10.1080/14733280701791918

National Audit Office. (2018). *Delivering STEM (science, technology, engineering and mathematics) skills for the economy*. https://www.nao.org.uk/report/delivering-stem-science-technology-engineering-and-mathematics-skills-for-the-economy/

Newton, L. D., & Newton, D. P. (1998). Primary children's conceptions of science and the scientist: Is the impact of a National Curriculum breaking down the stereotype? *International Journal of Science Education*, *20*(9), 1137–1149. https://doi.org/10.1080/0950069980200909

Noble, S., McLennan, D., Noble, M., Plunkett, E., Gutacker, N., Silk, M., & Wright, G. (2019). *The English Indices of Deprivation 2019: Research report*. Ministry of Housing, Communities and Local Government. https://www.gov.uk/government/publications/english-indices-of-deprivation-2019-research-report

Nowell, L. S., Norris, J. M., White, D. E., & Moules, N. J. (2017). Thematic analysis: Striving to meet the trustworthiness criteria. *International Journal of Qualitative Methods*, *16*, 1–13. https://doi.org/10.1177/1609406917733847

OECD. (2018). *Equity in education: Breaking down barriers to social mobility*. OECD Publishing. https://doi.org/10.1787/9789264073234-en

Ofcom. (2020). *Ofcom nations and regions technology tracker 2020*. https://www.ofcom.org.uk/__data/assets/pdf_file/0037/194878/technology-tracker-2020-uk-data-tables.pdf

Ofsted. (2021). *Research review series: Science*. https://www.gov.uk/government/publications/research-review-series-science/research-review-series-science

Owens, J., & de St Croix, T. (2020). Engines of social mobility? Navigating meritocratic education discourse in an unequal society. *British Journal of Educational Studies*, *68*(4), 403–424. https://doi.org/10.1080/00071005.2019.1708863

Padwick, A., Dele-Ajayi, O., Davenport, C., & Strachan, R. (2016). Innovative methods for evaluating the science capital of young children. *2016 IEEE Frontiers in Education Conference (FIE)*, 1–5. https://doi.org/10.1109/FIE.2016.7757680

Peterson, R. A., & Kern, R. M. (1996). Changing highbrow taste: From snob to omnivore. *American Sociological Review*, *61*(5), 900–907. https://doi.org/10.2307/2096460

Punch, K., & Oancea, A. (2014). *Introduction to research methods in education* (2nd ed.). SAGE.

Pyle, A. (2013). Engaging young children in research through photo elicitation. *Early Child Development and Care*, *183*(11), 1544–1558. https://doi.org/10.1080/03004430.2012.733944

Quaye, J., & Pomeroy, D. (2021). Social class inequalities in attitudes towards mathematics and achievement in mathematics cross generations: A quantitative Bourdieusian analysis. *Educational Studies in Mathematics*. https://doi.org/10.1007/s10649-021-10078-5

Ridgeway, M. L. (2019). Deprogramming deficit: A narrative of a developing Black critical STEM education researcher. *Taboo: The Journal of Culture and Education*, *18*(1), 157–167.

Scott, C. M. (2014). The use of photo elicitation interviews in summer science programs to determine children's perceptions of being a scientist. *International Journal of Science Education, Part B*, *4*(2), 147–171. https://doi.org/10.1080/21548455.2013.789148

Sevilla, A., Phimister, A., Krutikova, S., Kraftman, L., Farquharson, C., Costa Dias, M., Cattan, S., & Andrew, A. (2020). *Family time use and home learning during the COVID-19 lockdown* (IFS ReportR178). Institute for Fiscal Studies. https://doi.org/10.1920/re.ifs.2020.0178

Shimwell, J., DeWitt, J., Davenport, C., Padwick, A., Sanderson, J., & Strachan, R. (2021). Scientist of the week: Evaluating effects of a teacher-led STEM intervention to reduce stereotypical views of scientists in young children. *Research in Science & Technological Education*. https://doi.org/10.1080/02635143.2021.1941840

Skilling, K. (2020). Student STEM beliefs and engagement in the UK: How they shift and are shaped through integrated projects. In J. Anderson & Y. Li (Eds.), *Integrated approaches to STEM education: An international perspective* (pp. 251–270). Springer International Publishing. https://doi.org/10.1007/978-3-030-52229-2_14

Smith, E. (2010a). Is there a crisis in school science education in the UK? *Educational Review*, *62*(2), 189–202. https://doi.org/10.1080/00131911003637014

Smith, E. (2010b). Do we need more scientists? A long-term view of patterns of participation in UK undergraduate science programmes. *Cambridge Journal of Education*, *40*(3), 281–298. https://doi.org/10.1080/0305764X.2010.502886

Spyrou, S. (2011). The limits of children's voices: From authenticity to critical, reflexive representation. *Childhood*, *18*(2), 151–165. https://doi.org/10.1177/0907568210387834

STEMettes. (2014, May 7). Stemettes pledge in the UK government Your Life campaign. *STEMettes Blog*. https://stemettes.org/blog/2014/05/07/stemettes-pledge-in-the-uk-government-your-life-campaign/

Sutton, C. (2011). Social surveys: Design to analysis. In T. May (Ed.), *Social research: Issues, methods and process* (4th ed.). McGraw Hill.

Tan, E., & Barton, A. C. (2010). Transforming science learning and student participation in sixth grade science: A case study of a low-income, urban, racial minority classroom. *Equity & Excellence in Education*, *43*(1), 38–55. https://doi.org/10.1080/10665680903472367

The Committee of Public Accounts. (2018). *Delivering STEM skills for the economy* (HC 691). House of Commons. https://publications.parliament.uk/pa/cm201719/cmselect/cmpubacc/691/691.pdf

Tintori, A., & Palomba, R. (2017). The most common stereotypes about science and scientists: What scholars know. In *Turn on the light on science* (pp. 1–18). Ubiquity Press. https://www.ubiquitypress.com/site/chapters/m/10.5334/bba.b/

Trew, A., Pemberton, K., Ellis, R., Tyler, P., Nash, J., Early, C., & Shallcross, D. (2021). I bet you didn't know...What's new in PSTT's cutting-edge science in primary schools project. *Primary Science*, *May/June*(168). https://www.ase.org.uk/system/files/17-20_14.pdf

Tsui, A. (2018, September 21). Raising science capital at Willow Brook. *Royal Society Blog*. https://royalsociety.org/blog/2018/09/raising-science-capital-at-willow-brook/

Upadhyay, B. R. (2006). Using students' lived experiences in an urban science classroom: An elementary school teacher's thinking. *Science Education*, *90*(1), 94–110. https://doi.org/10.1002/sce.20095

Varelas, M., Kane, J. M., & Wylie, C. D. (2011). Young African American children's representations of self, science, and school: Making sense of difference. *Science Education*, *95*(5), 824–851. https://doi.org/10.1002/sce.20447

Wallace, M. F. G. (2018). The paradox of un/making science people: Practicing ethico-political hesitations in science education. *Cultural Studies of Science Education*, *13*(4), 1049–1060. https://doi.org/10.1007/s11422-017-9831-3

Wilson-Lopez, A., & Acosta-Feliz, J. (2021). Transnational Latinx youths' workplace funds of knowledge and implications for assets-based, equity-oriented engineering education. *Journal of Pre-College Engineering Education Research (J-PEER)*, *11*(1), 113–137. https://doi.org/10.7771/2157-9288.1289

Yang, Y. (2014). Bourdieu, practice and change: Beyond the criticism of determinism. *Educational Philosophy and Theory*, *46*(14), 1522–1540. https://doi.org/10.1080/00131857.2013.839375

YESTEM Project UK Team. (2020). *The Equity Compass: A tool for supporting socially just practice.*

Yin, R. K. (1994). *Case study research: Design and methods* (2nd ed.). Sage.

Yosso, T. J. (2005). Whose culture has capital? A critical race theory discussion of community cultural wealth. *Race Ethnicity and Education*, *8*(1), 69–91. https://doi.org/10.1080/1361332052000341006

Zimmerman, H. T., & Bell, P. (2014). Where young people see science: Everyday activities connected to science. *International Journal of Science Education, Part B*, *4*(1), 25–53. https://doi.org/10.1080/21548455.2012.741271

APPENDICES

Appendix A: Initial recruitment email

Dear [*NAME*],

I am a Master's student researcher at the University of Oxford and I am conducting a research study that aims to explore how young people engage with science in their everyday lives. Please can I ask for your help with engaging children aged 8–11 years old?

If you would be happy to, please could I ask you to share the paragraph below with children (8–11 years old) and their parents/guardians:

Hello! I'm [*NAME*], a student researcher at the University of Oxford and I would like to invite all children aged 8–11 years old and their guardians to take part in a research study exploring how young people engage with science in their everyday lives. I am interested in working with everyone, no matter their interest in science! Taking part would involve children and guardians completing a short online questionnaire that takes about 10 minutes and children creating a diary for at least one day that shares experiences that they consider to be related to science. If they would like to, children can also take part in an optional online interview or complete an activity at home in their own time. To find out more, please ask children to watch this 3-minute information video ([*LINK*]; captions provided) and please read this information sheet for guardians ([*LINK*]). I can also print and post this information and/or discuss taking part over the phone ([*NUMBER*]). I can also be contacted via email at [*EMAIL*].

If I can provide the information in any other formats please let me know. If you would like to find out more detailed information about the study, why it's being done and how it's being conducted, please take a look at the information sheet for guardians ([*LINK*]). At the end of the project I will share the findings with all involved.

I would be incredibly grateful for any support, thank you so much!

Appendix B: Information video for children - transcript

Hi, I'm [*NAME*]. I am a student and researcher at university and I have a question that I would really like to investigate with you. So I'm here to ask if you would like to help me with it? I would really like to find out from you how science is a part of your lives. I'm interested in this because not everyone feels like science is for them. So by finding out more about how each of you think about science, we can try and make science be something that everyone feels they can do and enjoy, and no one misses out.
People haven't really asked this question with children your age so I'm excited to work with you.

If you think you'd like to help me, there are 2 things that I will ask you and a parent or guardian to do at home:

1. I would ask you to answer a few questions in a form online.
2. I would ask you to create a diary of things in your day that you think are related to science. You could do this by taking photos, or recording yourself speaking, or by writing it down.

Plus, if you wanted to, I would love to chat and do some activities with you over a video call, or if you don't fancy that you could do those activities at home in your own time. But if you just want to do the diaries and questions, that's no problem.

Anyone aged 8–11 years old is welcome to take part. I would like to know about how science is a part of all your lives, it doesn't matter how interested you are in science or not. There are no wrong answers and it is absolutely not a test, I hope you'll find it fun.

You don't have to help me with this investigation, it is totally up to you. And you can change your mind at any point. If you do want to help, please talk to your parent or guardian about it. If they are happy for you both to take part, we'll get started as soon as possible!
At the end of it all, I would really like to write about what you share with me so that other people, like teachers and other children, can learn about it too. If you have any questions or you're worried about anything, try asking your parent or guardian, and you can both always ask me too.

So if you want to help me, thank you! Don't forget to talk to your parent or guardian about it. And I'm excited to hopefully work with some of you soon. Thank you.

Appendix C: Information sheet for parents/guardians

Department of Education
University of Oxford
15 Norham Gardens
Oxford, OX2 6PY

[*RESEARCHER NAME*]
[*RESEARCHER EMAIL*]

INFORMATION SHEET FOR PARENTS/GUARDIANS

Exploring science capital with primary-school-aged children

Ethics Approval Reference: ED-CIA-20-181

In partnership with the Department of Education at the University of Oxford, you and your child (aged between 8 and 11 years old) are invited to take part in a research study investigating how young people engage with science in their everyday lives. Before you decide whether to take part, please ask children to watch this video: [*LINK*] (3 minutes, captions available) and please read the following information, which explain why the study is being done and what participating would involve. If you have any questions please do get in touch with [*NAME*], the researcher, at: [*EMAIL*].

What is the study trying to find out?

We are interested in what children identify as science, how they think about science, who they know that they consider to be science people, and how they engage with science in their everyday lives.

What will happen if my child and I take part in the study?

First, you will be asked to complete a short online consent form and questionnaire. Second, children will be asked to create a diary to report their experiences that they consider to be related to science. This can be done in whatever ways suit your child and you. For example, by taking photos, making audio recordings, and/or writing diary entries. We ask for children to diary at least one day, and we welcome diaries for up to seven days. For safeguarding reasons, we ask that parents/guardians are in charge of transferring children's diary entries to the researcher by WhatsApp or email.

Children and parents/guardians will also be invited to take part in an optional online interview with the researcher or to complete an optional home activity to explore what science means to you. Please indicate in the consent form if you and your child would be interested in taking part in either option.

Why have my child and I been invited to take part?

Any child aged between 8 and 11 years old is invited to take part. Very little research on this topic has been carried out with this age group. We are interested in all children's views related to science, not only from those that are interested in science. We would really like your child to take the lead on how they engage with this research project (with any necessary support from a parent/guardian).

Do my child and I have to take part?
No, it is completely up to you and your child. If you do participate, you and your child may withdraw your data from the study at any time, without giving a reason, by advising the researcher of this decision.

When will the research take place?
In March, April and May 2021. Ideally, we ask that the consent form, questionnaire and diaries are submitted by the end of April, and that interviews take place or the home activity is completed by mid-May (if you've opted in to these).

What are the advantages/disadvantages of taking part?
There are no known risks to taking part. All contact and transfer of diary data to the researcher will be through parents/guardians via WhatsApp with end-to-end encryption or via the researcher's institutional email address which is overseen by the University of Oxford.

Your participation will contribute to research into making science more accessible to all children. Children and parents/guardians will be offered a certificate for participating in the project.

What happens to the data provided?
The information you or your child provide during the study is the research data. Any research data from which you or your child can be identified, for example, name, date of birth, or an audio recording, is known as personal data. Digital personal data will be encrypted and stored on the University storage service. Every effort will be made to preserve confidentiality in the final report. Personal data will be kept only for as long as it is needed to conduct the research, after which it will be deleted. According to University policy, consent forms will be retained by the researcher for 3 years after reporting the work of the research. The researcher and supervisor will have access to the research data.

Will the research be published?

The research will be written up as a student's Master's thesis. On successful submission of the thesis, it may be deposited both in print and online in the University archives to facilitate its use in future research. If so, the thesis will be openly accessible. A summary of the findings will be available to interested families.

Who is conducting this research?
The research project is organised by [*NAME*] of Oxford University, who is a Master's student in the Department of Education. The research is part-funded by [*SPONSOR*]. This study has been reviewed by and received ethics clearance through the University of Oxford's Central University Research Ethics Committee (Ethics Approval Reference: ED-CIA-20-181).

What if there is a problem?
If you have a concern about any aspect of this study, please contact [*NAME*] ([*EMAIL*]) or the supervisor of this project, [*NAME*] ([*EMAIL*]), and we will do our best to answer your query. If you remain unhappy or wish to make a formal complaint, please contact the Chair of the Research Ethics

Committee at the Department of Education, University of Oxford who will seek to resolve the matter as soon as possible.
Email: liam.gearon@education.ox.ac.uk
Address: Department of Education, University of Oxford, 15 Norham Gardens, Oxford, OX2 6PY

Data Protection

The University of Oxford is the data controller with respect to you and your child's personal data and, as such, will determine how you and your child's personal data is used in the study. The University will process you and your child's personal data for the purpose of the research outlined above. Research is a task that we perform in the public interest. Further information about your rights with respect to you and your child's personal data is available from https://compliance.web.ox.ac.uk/individual-rights.

What should I do next?

Please discuss the research project with your child. If you are both happy to take part in the study (thank you!) please complete these two forms:

- The online consent form (we expect this to take about 5 minutes): [*LINK*]
- The online questionnaire (about 10 minutes): [*LINK*]

The researcher will then be in touch to provide further information on the next steps. If you have any issues accessing or completing the forms online please contact the researcher. The forms could be printed and posted to you if you would prefer.

Thank you so much for considering being involved and taking the time to read this information! If you would like to discuss the research or if you have any questions, please contact:

[*RESEARCHER NAME*]
[*RESEARCHER EMAIL*]
[*RESEARCHER MOBILE*]

Appendix D: Questionnaire

Science in your life research study - questionnaire

University of Oxford Ethics Approval Reference: ED-CIA-20-181

* Required

Information and consent

Thank you for thinking about completing this questionnaire.

The aim of the questionnaire is to explore children's thoughts, feelings and experiences related to science. The first and main set of questions are for children to answer, and the second set of questions are for parents/guardians to answer. We predict the survey will take around 10 minutes to complete. Please be aware that the survey won't save your responses until you click submit at the end.

You may stop participating and/or withdraw your data at any time by contacting the researcher. Please feel free to ask any questions or contact the researcher by sending an email to [EMAIL].

Please confirm below whether you wish to continue. Thank you!

1. Parent/guardian - please provide your first and last name *

2. Parent/guardian - Please tick the option that applies to you. *

- ◯ I agree for me and my child to take part in this questionnaire
- ◯ I agree to take part in this questionnaire but I do not agree for my child to take part
- ◯ I do not agree to take part in this questionnaire but I agree for my child to take part
- ◯ I do not agree for me or my child to take part in this questionnaire

3. Child - Are you happy to answer some questions? *

- ◯ Yes
- ◯ No

Questions for children

This questionnaire asks about you and science - how you feel, who you know, and what you do. It is is not a test, we want to know what you think. There are no right or wrong answers.

4. How much do you agree or disagree with the sentences below?

Please answer for every sentence.

	Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree	I do not know
I see myself as a science person	◯	◯	◯	◯	◯	◯
People who are like me work in science	◯	◯	◯	◯	◯	◯
Anyone can become a scientist	◯	◯	◯	◯	◯	◯
I want to become a scientist	◯	◯	◯	◯	◯	◯
I would like to have a job that uses science	◯	◯	◯	◯	◯	◯

5. Can you think of anyone in your life who you would describe as a science person? Tick who they are to you (e.g. are they your friend, or your parent).

If you can think of more than one person, please tick all that apply.

- ☐ Parents or guardians
- ☐ Siblings (brothers or sisters)
- ☐ Extended family members (grandparents, aunts, uncles, cousins)
- ☐ Friends or neighbours
- ☐ Someone I know from my community
- ☐ No one
- ☐ _____

Other

6. How much do you agree or disagree with the following sentences?

	Strongly agree	Agree	Neither agree or disagree	Disagree	Strongly disagree	I do not know
A science qualification can help you get many different types of job	◯	◯	◯	◯	◯	◯
At least one of my parents or guardians thinks science is very interesting	◯	◯	◯	◯	◯	◯
At least one of my parents or guardians has explained to me that science is useful for my future	◯	◯	◯	◯	◯	◯
I know how to use scientific evidence to make an argument	◯	◯	◯	◯	◯	◯
My teachers have specifically encouraged me to continue with science in the future	◯	◯	◯	◯	◯	◯
My teachers have explained to me science is useful for my future	◯	◯	◯	◯	◯	◯
It is useful to know about science in my daily life	◯	◯	◯	◯	◯	◯

7. When you are not in school, how often do you talk about science with other people?

- ◯ Never or rarely (about once a year)
- ◯ A few times a year
- ◯ About once a month
- ◯ About once a week
- ◯ Almost every day or more

8. Who do you talk with about science?

Please tick all that apply.

- [ ] Parents or guardians
- [ ] Siblings (brothers or sisters)
- [ ] Extended family members (grandparents, aunts, uncles, cousins)
- [ ] Friends
- [ ] Teachers
- [ ] Scientists
- [ ] No one
- [ ] Other

9. Do you know anyone (family or friends) who works in science or has a job that uses science? Who are they?

Please tick all that apply.

- [ ] Parents or guardians
- [ ] Siblings (brothers or sisters)
- [ ] Extended family members (grandparents, aunts, uncles, cousins)
- [ ] Friends or neighbours
- [ ] Someone I know from my community
- [ ] No one
- [ ] Other

10. How often do you go to a lunchtime or after-school science club?

- ◯ Never
- ◯ At least once, more than a year ago
- ◯ At least once a year
- ◯ At least once a term
- ◯ At least once a month

11. When not in school, how often do you read books or magazines about science?

- ◯ Never or rarely (once a year)
- ◯ Occasionally (few times a year)
- ◯ Sometimes (once every month)
- ◯ Regularly (once every week)
- ◯ Always (every day or every other day)

12. When not in school...

	Never	At least once, more than a year ago	At least once a year	At least once a term	At least once a month
How often do you go to a science centre, science museum or planetarium?	◯	◯	◯	◯	◯
How often do you visit a zoo or aquarium?	◯	◯	◯	◯	◯

13. What school do you go to?

14. What is your age?

15. What is your gender?

You don't have to answer.

Thank you so much!

Please could you ask your parent/guardian to answer the next set of questions?

Questions for parents/guardians

16. Please confirm whether you are happy to answer some questions.

- ◯ Yes
- ◯ No

17. Science engagement has been shown to be related to gender, ethnicity, and socioeconomic status. To help us explore this relationship among primary school students, please could you provide us with any of the following information:

    What is your child's ethnicity?

18. What is your child's postcode?
    (Postcode data will be classified according to the English Indices of Deprivation 2019)

19. Is your child eligible for pupil premium/free school meals?

- ◯ Yes
- ◯ No
- ◯ Don't know/not sure/prefer not to say

Thank you!

20. To say thank you for participating in this research, we would like to send you a certificate. Please let us know how you would prefer to receive this.

- ◯ Please send by email
- ◯ Please post to an address (please provide this below)

21. If you selected that you would like the certificate posted, please provide the address below. (After posting the certificate, this information will be deleted.)

Appendix E: Interview schedule

Introduction

Welcome. Thank you so much for taking part in this research study.

Brief:

- I will ask you some questions and we'll talk about your answers. They're all about how science is a part of your life, and there aren't any wrong answers.
- As you'll see, I will try to make notes as we go. Please do tell me if I've got anything you've said wrong.
- I'm expecting that this chat will take up to half an hour, but it's up to you. We can take a break or stop at any point.
- Can you confirm that an adult will be present in the room?
- Please could you avoid using the chat function for data privacy reasons.
- If you are happy to go ahead, I will start recording us talking in a moment. It's completely up to you whether you turn your video on/off, only our voices will be recorded.
- Do you have any questions? Are you happy to start?

Main interview

1. For each of the activities on the screen, can you tell me whether you think they are related to science? How did you decide?
    a. Playing games
    b. Taking care of pets or animals
    c. Watching a film or TV

2. Questions about diary entries
    a. Can you see the screen with some of your diaries? Can you tell me how you decided what to put in your diary?
    b. Questions about specific diary entries.
    c. Check that consent was obtained for any with people in.
    d. Is there a diary day or activity that you want to talk about?

3. Questions about what makes someone a science person
   Explore reasons behind answers to questions 4 and 5 in the questionnaire e.g.
    a. You said you [agree] that you see yourself as a science person - can you tell me why?

b. You also said that you have [lots of] people in your life that you would describe as science people? Can you tell me about them? What makes them science-y?

4. For each of the activities on the screen, can you tell me whether you think they are important, not important, or don't really matter for being a science person?
    a. Talking about science with other people
    b. Going to science clubs
    c. Reading about science
    d. Going to science centres or science museums
    e. Going to zoos or aquariums

    What else do you think is important? What do science people do/think/know/enjoy?

Conclusion

Thank you! I will stop recording.

Explain what will happen with the information provided in the interview (and study in general).

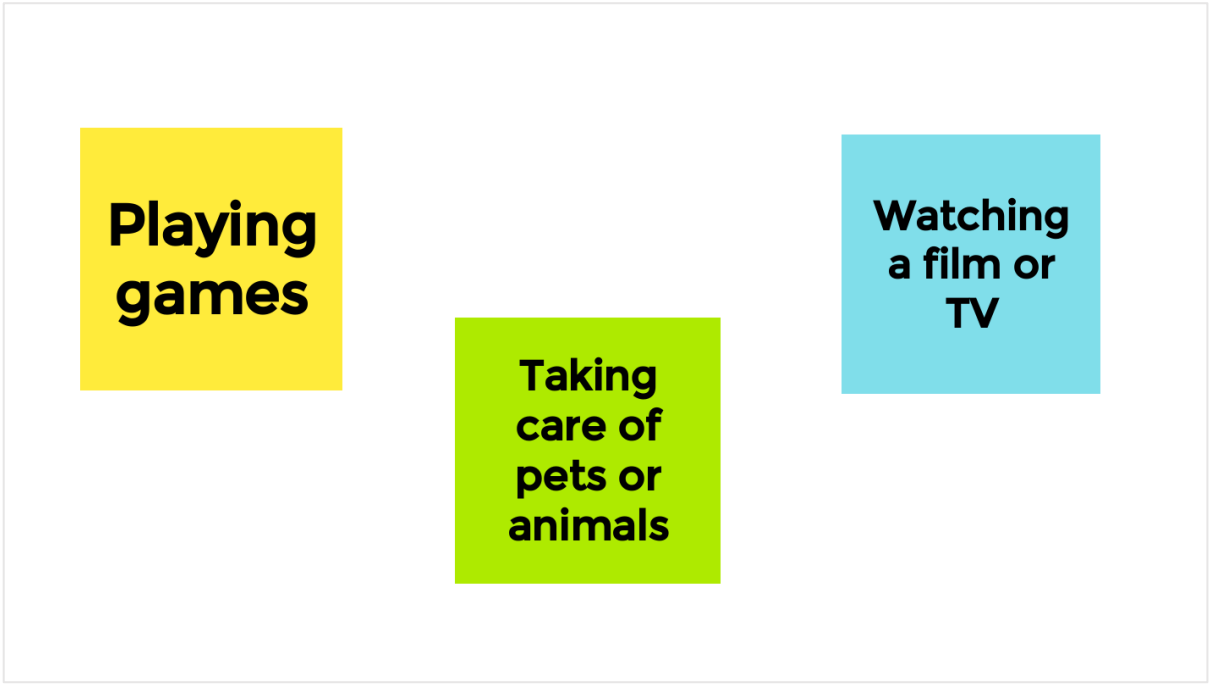
Are you both still happy for me to use your diary entries and things that you've said when I write about this research? (Photos of people will not be used.)

Do you have any questions or anything else you want to say?

Thank you!

Appendix F: Example visual prompts for online interview

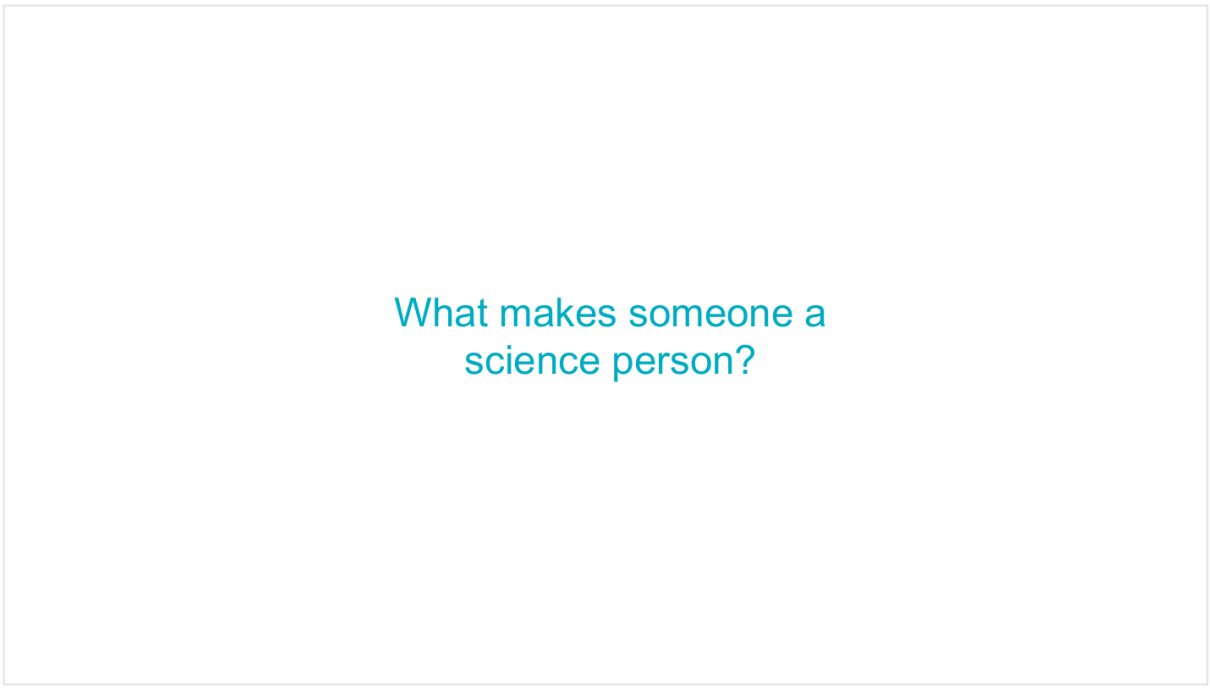
Interview question 1



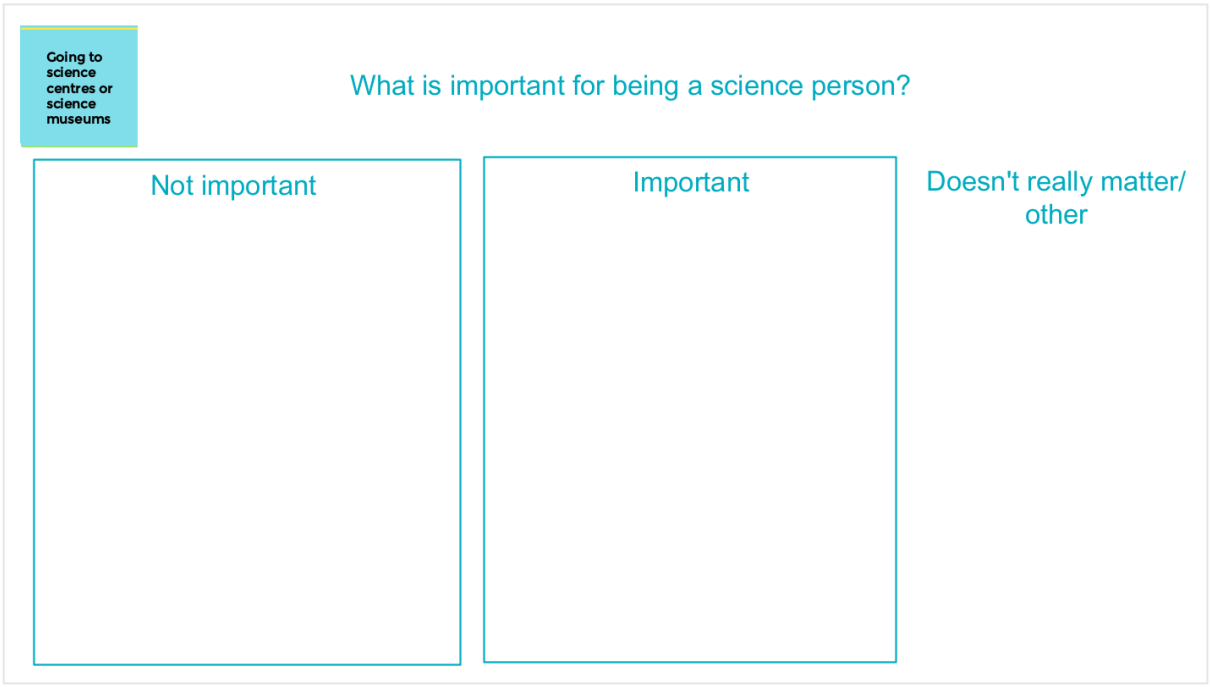
Interview question 2 (example diary entries)



Interview question 3



Interview question 4



Appendix G: Example offline interview activity sheet

1

Do you think each of these activities are related to science?

Playing games

Yes / No because...

Taking care of pets or animals

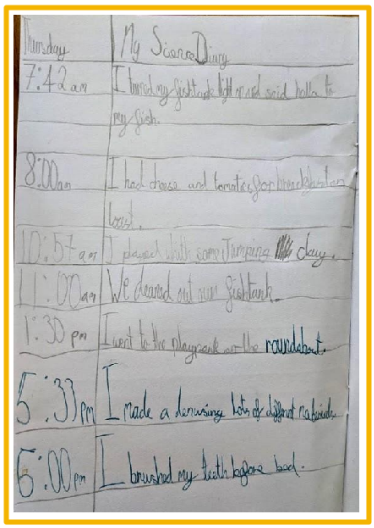
Yes / No because...

Watching a film or TV

Yes / No because...

2

Thank you for your diaries!



How did you decide what to include in your diaries?

Can you tell me any more about any of your diary entries?
For example, why was playing with clay and going to the park related to science?

3

You said that you 'neither agree or disagree' that you see yourself as a science person - can you explain why?

Can you add to the two mind maps below?

What makes you feel like a science person?

What makes you feel NOT like a science person?

4

What is important for being a science person?

Draw a line between each idea on the left and one of the three boxes on the right to show whether you think it's important, not important, or doesn't really matter for being a science person

- Going to science clubs
- Going to zoos or aquariums
- Going to science centres or museums
- Reading about science
- Talking about science with other people

Not important

Important

Doesn't really matter

You said someone in your community is a science person - can you explain why?

Appendix H: Science capital index items and scoring

Item	Response options and score
A science qualification can help you get many different types of job	-2 for 'Strongly disagree', -1 for 'Disagree', 0 for 'Neither agree nor disagree', 1 for 'Agree', 2 for 'Strongly agree'
At least one of my parents or guardians thinks science is very interesting	-1 for 'Strongly disagree', -0.5 for 'Disagree', 0 for 'Neither agree nor disagree', 0.5 for 'Agree', 1 for 'Strongly agree'
At least one of my parents or guardians has explained to me that science is useful for my future	-2 for 'Strongly disagree', -1 for 'Disagree', 0 for 'Neither agree nor disagree', 1 for 'Agree', 2 for 'Strongly agree'
I know how to use scientific evidence to make an argument	-2 for 'Strongly disagree', -1 for 'Disagree', 0 for 'Neither agree nor disagree', 1 for 'Agree', 2 for 'Strongly agree'
My teachers have specifically encouraged me to continue with science in the future	-2 for 'Strongly disagree', -1 for 'Disagree', 0 for 'Neither agree nor disagree', 1 for 'Agree', 2 for 'Strongly agree'
My teachers have explained to me science is useful for my future	-2 for 'Strongly disagree', -1 for 'Disagree', 0 for 'Neither agree nor disagree', 1 for 'Agree', 2 for 'Strongly agree'
It is useful to know about science in my daily life	-1 'Strongly disagree', -0.5 for 'Disagree', 0 for 'Neither agree nor disagree', 0.5 for 'Agree', 1 for 'Strongly agree'
When you are not in school, how often do you talk about science with other people?	-2 for 'Never or rarely (once a year)', -1 for 'A few times a year', 0 for 'About once a month', 1 for 'About once a week', 2 for 'Almost every day or more'
Who do you talk with about science?	0.5 for each response: ['Friends', 'Siblings (brothers or sisters)', 'Parents or guardians', 'Extended family members (grandparents, aunts, uncles, cousins)', 'Scientists', 'Teachers', 'Other (please specify)']; 0 for 'No one'
Do you know anyone (family or friends) who works in science or has a job that uses science? Who are they?	2 for 'Parents or guardians', 1 for each other response ['Siblings (brothers or sisters)', 'Extended family members (grandparents, aunts, uncles, cousins)', 'Friends or neighbours', 'Someone I know from my community', 'Other (please specify)'; 0 for No one
How often do you go to a lunchtime or after-school science club?	-2 for 'Never', -1 for 'At least once, more than a year ago', 0 for 'At least once a year', 1 for 'At least once a term', 2 for 'At least once a month'

When not in school, how often do you read books or magazines about science?	-2 for ‘Never or rarely (once in a year)’, -1 for ‘Occasionally (few times a year)’, 0 for ‘Sometimes (once every month)’, 1 for ‘Regularly (once every week)’, 2 for ‘Always (every day or every other day)’
How often do you go to a science centre, science museum or planetarium?	-2 for ‘Never’, -1 for ‘At least once, more than a year ago’, 0 for ‘At least once a year’, 1 for ‘At least once a term’, 2 for ‘At least once a month’
How often do you visit a zoo or aquarium?	-1 for ‘Never’, -.5 for ‘At least once, more than a year ago’, 0 for ‘At least once a year’, .5 for ‘At least once a term’, 1 for ‘At least once a month’

Note: scoring reproduced from Moote et al. (2021).

Appendix I: Initial codebook

	LABEL	DEFINITION
1	**Science-related event**	Name of the event or experience reported by or discussed with children that they considered to be science-related, plus elaboration/description if provided. Includes events used by the researcher in the interview as discussion points and events identified independently by children.
2	**Categorisation of science-related event**	How and/or why children categorised or reported an event as science-related.
3	**Categorisation of science people**	Whether and how children categorised themselves and others as science people.
4	**Categorisation of not science-related**	How children categorised events or people as not related to science, or not important for categorising something as being science-related.
5	**Dimension of science capital: Scientific forms of cultural capital**	
5.1	Scientific literacy	Evidence of children's scientific literacy: scientific knowledge, skills, an understanding of how science works, critical analysis skills, and confidence in knowledge of science. Not including children's identification and categorisation of science-related events.
5.2	Science-related dispositions	Children's expression of science-related dispositions: seeing and valuing science as relevant to everyday life. Not including children's identification and categorisation of science-related events.
5.3	Knowledge about the transferability of science	Children express knowledge about the transferability of science: an understanding of the worth and application of scientific skills, knowledge and qualifications, particularly in terms of future careers/aspirations.
6	**Dimension of science capital: Science-related behaviours and practices**	
6.1	Science media consumption	Evidence of children consuming science through media, for example, science-related television, books, magazines and internet content.
6.2	Participation in out-of-school science engagement	Participation in informal/out-of-school science learning environments: in designed spaces such as zoos; community spaces such as science clubs; and/or everyday contexts such as at home.

7	**Dimension of science capital: Science-related forms of social capital**	
7.1	Knowing people in science-related roles	Evidence of a meaningful relationship with someone who works in a science-related role such as parents, family members, neighbours, and friends.
7.2	Family science capital	Evidence of family science skills, knowledge, qualifications, and interests.
7.3	Talks about science in everyday life	Evidence of children talking with key people in their life about science, for example, with friends, siblings, parents, neighbours, community members.

Appendix J: Final codebook

	LABEL	DEFINITION	EXAMPLE
1	**Science-related event**	An event or experience reported by or discussed with children that they considered to be science-related, plus elaboration/description if provided. Not including explanation as to why it's science-related. Includes events used by the researcher in the interview as discussion points as well as events identified independently by children.	"Fireworks" "Car wheels"
1.1	Narrow definition (field-led)	Traditionally science-related events or experiences, such as going to science museums or science clubs, doing experiments/using science kits at home; fixing/building things at home; going on nature walks; programming computers.	"Saturday Science Club!"
1.2	Broad definition (child-led)	Events or experiences that children identified as science-related and that have not been included by the narrow definition.	"Church" "Art club"
2	**Science-related events are categorised by…**	How and/or why children categorised or reported an event as science-related.	
2.1	How things work	Children's descriptions of science-related events that suggest knowledge of or enquiry into how things work, both inward- (how I work) and outward-looking (how things around me work).	"It involves natural things made into other things"
2.2	Components of science	Children's identification/explanation of something as science-related by linking it to topics/categories of science (possibly framed by school science but not explicitly). Not including higher-level thinking, for example, the code 'How the sound travelled to my ears' includes higher-level thinking/application and so has not been included in this theme even though it relates to the topic of sound.	"Cooking is science because it involves … change of state"
2.3	Learning	Categorisations that involved learning, particularly learning by doing or how to do something, and applying knowledge/experience/skill to solve a problem or find things out.	"Because you have to find out where the pieces go in the model"
2.4	Being	Categorisations that related to qualities of a person.	"Because you have to have intelligence"
2.5	Invention	Explaining something as science-related because it was made possible/created using science.	"Because someone did a scientific experiment to create Jumping Clay"

3	**Science people…**	How children categorised themselves and others as science people. Includes inferences from how children categorised events or people as not related to science, or not important for categorising something as being science-related.	
3.1	Engage in science-related interests and activities	Categorisations that included engaging in, a desire to engage in, and/or enjoyment of engaging in interests or activities that children have defined as science-related. Includes recognition that some people may not have access to or interest in engaging with science-related activities but that does not exclude them from being a science person.	"Because I like drawing and art. And because I like watching telly and playing on the iPads."
3.2	Talk with people who are interested in science	Mention of how talking with people is linked to or can influence feeling like/perceiving someone as a science person.	"Another [science] person is Grandma because she normally asks me a few questions and there's a few words that she taught me"
3.3	Find things out	Linking being a science person with asking/answering questions and finding things out.	"because you find new things out and finding new things is important"
3.4	Have a science-related job	Identifying someone as a science person by their job.	"The person who is a science person is my science teacher"
4	**Dimension of science capital: Scientific forms of cultural capital**		
4.1	Scientific literacy	Evidence of children's scientific literacy: scientific knowledge, skills, an understanding of how science works, critical analysis skills, and confidence in knowledge of science. Not including children's identification and categorisation of science-related events.	Guardian: So where do you think it gets its energy from? Child: The electricity wires.
4.2	Science-related dispositions	Children's expression of science-related dispositions: seeing and valuing science as relevant to everyday life. Not including children's identification and categorisation of science-related events.	"Kind of see everything's related to science"
5	**Dimension of science capital: Science-related behaviours and practices**		
5.1	Science media consumption	Evidence of children consuming science through media, for example, science-related television, books, magazines and internet content.	"I been drawing some number block characters. ... blocks on

			the telly that help you count"
5.2	Participation in out-of-school science engagement	Participation in informal/out-of-school science learning environments: in designed spaces such as zoos; community spaces such as science clubs; and/or everyday contexts such as at home.	"I've recently been salvaging an old pallet and … managed to make it into this, sort of, chair"
6	**Dimension of science capital: Science-related forms of social capital**		
6.1	Knowing people in science-related roles	Evidence of a meaningful relationship with someone who works in a science-related role such as parents, family members, neighbours, and friends.	"My Granny is a science teacher"
6.2	Family science capital	Evidence of family science skills, knowledge, qualifications, interests and valuing science.	"Both my parents really really like science"
6.3	Talks about science in everyday life	Evidence of children talking with key people in their life about science, for example, with friends, siblings, parents, neighbours, community members.	"I asked her [Granny] a few things and she answered them and they were a little bit science-y."
7	**School science**	Explicit mention of or link to school science or the science curriculum by children or guardians. Not including mention of other lessons or aspects of school.	Guardian: And how does that link to the topic you've been doing at school? Child: Because our topic at school is animals.
8	**Potential value of participating in the research**	Description of positive experiences of taking part (from children or guardians).	"It was really nice for us all actually as a family to think about the science"

Appendix K: CUREC and amendment approval

Re: FW: CUREC - [redacted] - Ref ED-CIA-20-181

[redacted]@education.ox.ac.uk>
Fri 27/03/2020 16:05
To: Education Research Office <research.office@education.ox.ac.uk>; [redacted]

Dear [redacted]

Exploring how primary-school-aged children conceptualise science capital - CUREC Approval Reference ED-CIA-20-181

The above application has been considered on behalf of the Departmental Research Ethics Committee (DREC) in accordance with the procedures laid down by the University for ethical approval of all research involving human participants.

I am pleased to inform you that, on the basis of the information provided to DREC, the proposed research has been judged as meeting appropriate ethical standards, and accordingly, approval has been granted.

Should there be any subsequent changes to the project which raise ethical issues not covered in the original application you should submit details to research.office@education.ox.ac.uk for consideration.

As an additional note, many thanks for submitting such a thorough application - it makes the review process so much easier!

Good luck with your research study.

With kind regards,

[redacted]
Department of Education
University of Oxford

Re: CUREC - [redacted] - Ref ED-CIA-20-181

[redacted]@education.ox.ac.uk>
Tue 14/07/2020 08:06
To: [redacted]; Education Research Office <research.office@education.ox.ac.uk>

Dear [redacted]

Exploring how primary-school-aged children conceptualise science capital

The above application has been considered on behalf of the Departmental Research Ethics Committee (DREC) in accordance with the procedures laid down by the University for ethical approval of all research involving human participants.

I am pleased to inform you that, on the basis of the information provided to DREC, the proposed research has been judged as meeting appropriate ethical standards, and accordingly, approval has been granted.

Please note that the submission of data using WhatsApp has been approved due to the current COVID-19 circumstances. Please check for any future studies you may conduct whether the guidance has been updated.

Should there be any subsequent changes to your current project which raise ethical issues not covered in the original application you should submit details to research.office@education.ox.ac.uk for consideration.

Good luck with your research study.

With kind regards,

[redacted]
Department of Education
University of Oxford

Appendix L: Consent form

Science in your life research study - consent form

Exploring science capital with primary-school-aged children
CUREC Approval Reference: ED-CIA-20-181

You have been invited to take part in a study run by a Master's student at Oxford University investigating how children engage with science in their everyday lives. If you agree to take part, you will be asked to complete a questionnaire and create a diary of experiences that you consider to be related to science. Before agreeing to participate, please make sure you have watched the information video for children [redacted] and read the information sheet for parents/guardians [redacted].

You are very welcome to email any questions to the researcher, [redacted] or write your questions at the end of this form.

If you are both happy to take part, please complete this form and the questionnaire (a link is provided in the information sheet). [redacted] will then send you information about the next steps.

Thank you!

* Required

Section for children

Please read the questions below and answer 'Yes' if you agree or 'No' if you don't agree.

1. Has the researcher ([redacted]) or your parent/guardian explained the research project to you? *

- ◯ Yes
- ◯ No

2. Do you understand what the research project is about? *

- ◯ Yes
- ◯ No

3. Have you asked all the questions you want? *

- ◯ Yes
- ◯ No (please ask any questions you want in question 11)

4. Have your questions been answered in a way you understand? *

- ◯ Yes
- ◯ No

5. Do you understand it's OK to stop taking part or change your mind about any of these questions at any time? *

- ◯ Yes
- ◯ No

6. Are you happy to take part? *

- ◯ Yes
- ◯ No

7. Are you happy for [redacted] to write about what you say and do at the end of this project? (No one will be able to know it's you). *

- ◯ Yes
- ◯ No

8. If you don't want to take part, that's OK! No one will be upset with you. If you said no to any of the questions, that's OK too and it doesn't necessarily mean you can't take part - we can have a chat about it if you would like to.

   If you DO want to take part please write your first and last name below:

9. When [redacted] writes about this project, [redacted] won't use your name to talk about the information you have given, [redacted] give you a different name. If you would like to choose this name, please write it below:

10. You can write any questions or a message to [redacted] here:

Section for parents/guardians

Please read the following:
I have read and understood the details of the research study, and have had the opportunity to ask questions. I have received satisfactory answers to my questions. I understand that the project has received ethics clearance through the University of Oxford's ethical approval process for research involving human participants, and I understand who will have access to the data, how it will be stored and what will happen to the data at the end of the study. I understand that participation is voluntary and that my child and I are free to withdraw at any time, without giving any reason and without my child's education being affected in any way. I understand how to raise a concern or make a complaint.

11. Do you confirm the above and give permission for you and your child to take part in the research study? *

- ◯ Yes
- ◯ No

12. If applicable, do you agree for photographs of your child to be used in the research (but not in research outputs)? If yes, photographs will be accessed by the research team and used in analysis only, they will not be presented in the Master's dissertation or in any publications. *

- ◯ Yes
- ◯ No

13. Do you agree for audio recordings of you and your child to be transcribed and analysed (if applicable)? *

- ◯ Yes
- ◯ No

14. Do you agree for unidentifiable quotes of you to be used in research outputs e.g. the Master's dissertation and any publications (if applicable)? *

- ◯ Yes
- ◯ No

15. Do you agree for unidentifiable quotes of your child to be used in research outputs e.g. the Master's dissertation and any publications (if applicable)? *

- ◯ Yes
- ◯ No

16. Please provide your first and last name. *

17. To contact you about the next stages of the research and to provide support throughout the study, the researcher would like to contact you via email (please check your junk email!). Please provide your email address. *

18. Please indicate whether you would prefer to send your child's diary entries to the researcher by email or WhatsApp by providing your email address or phone number below. If you would like to use both or you're not sure, please provide both. *

19. In any research outputs, if required, the researcher will refer to participants by pseudonyms. If you would like to choose your own name, please write it below.

20. Please write any questions or a message to the researcher below.

21. How did you hear about this research study?

Interview/activity sheet

After you've sent your diary entries [redacted] would like to invite you both to take part in an optional online interview or to complete an optional activity sheet to explore what science means to you. We think the interview will take around 30 minutes. The home activity can be done in your own time.

22. Would you both be interested in finding out more about taking part in an interview or completing an activity sheet? *

- ◯ Yes - I would like to know more about the interview
- ◯ Yes - I would like to know more about the activity sheet
- ◯ No - I am happy doing the questionnaire and diary only